ASTRONOMY

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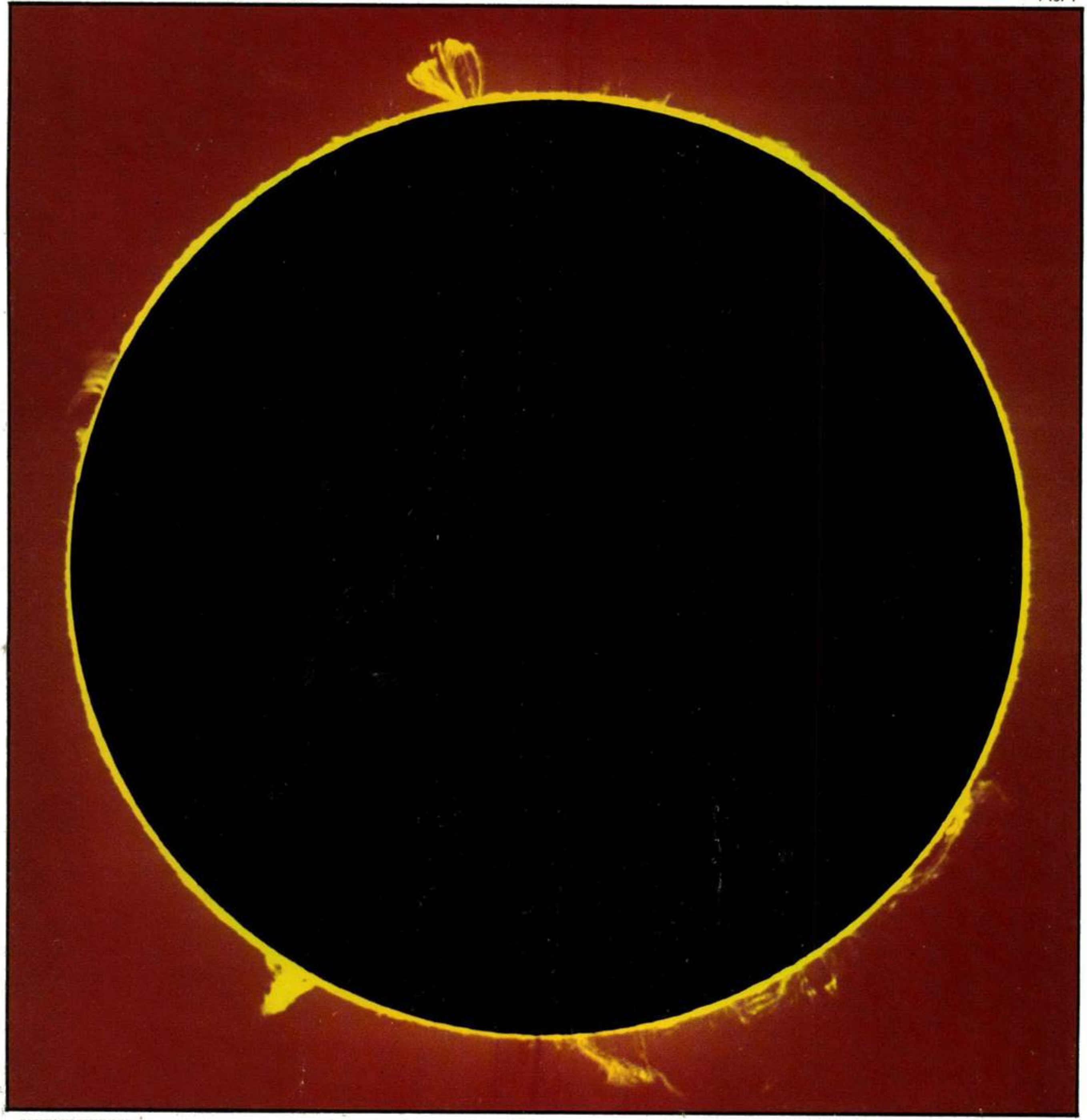

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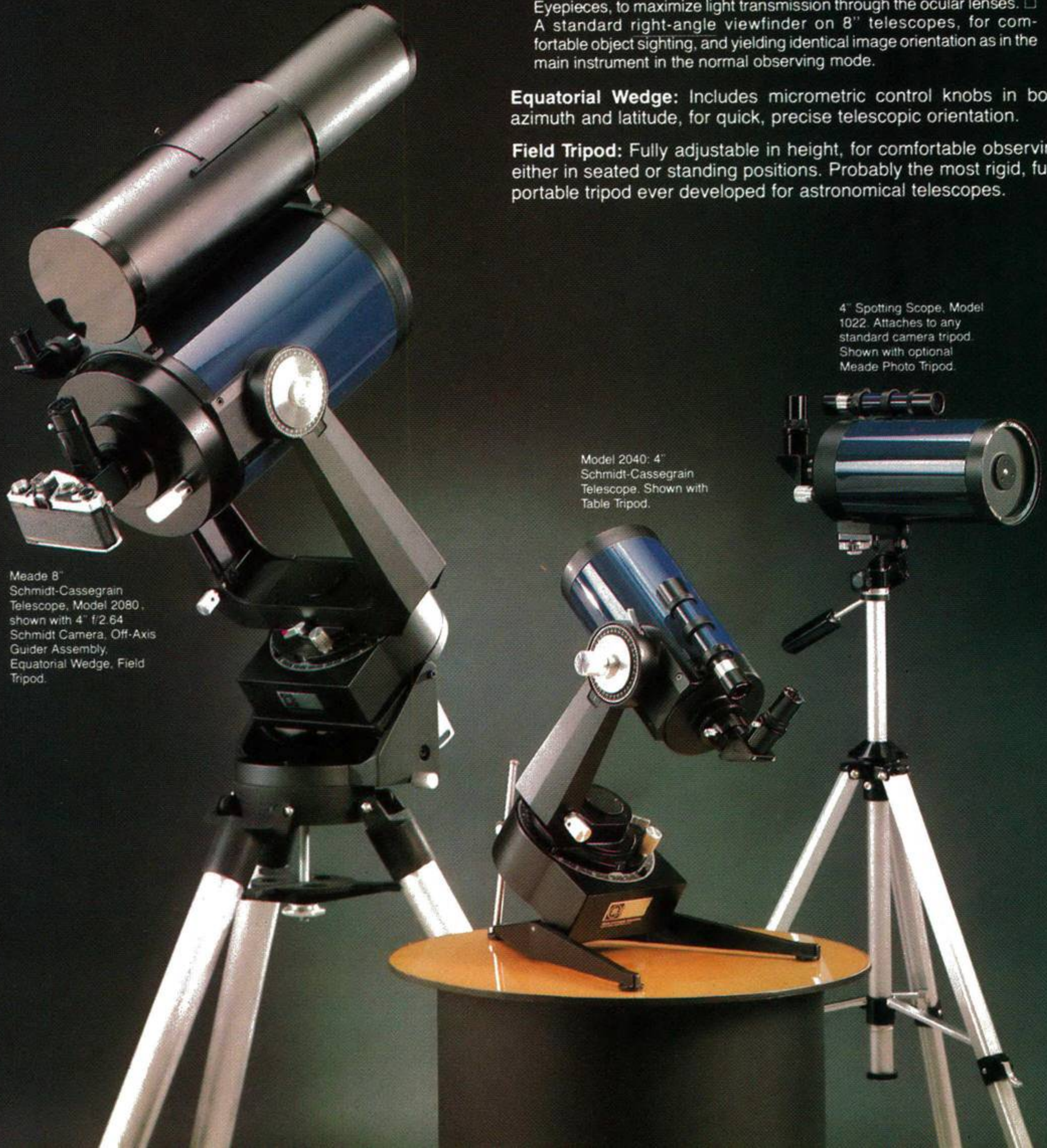

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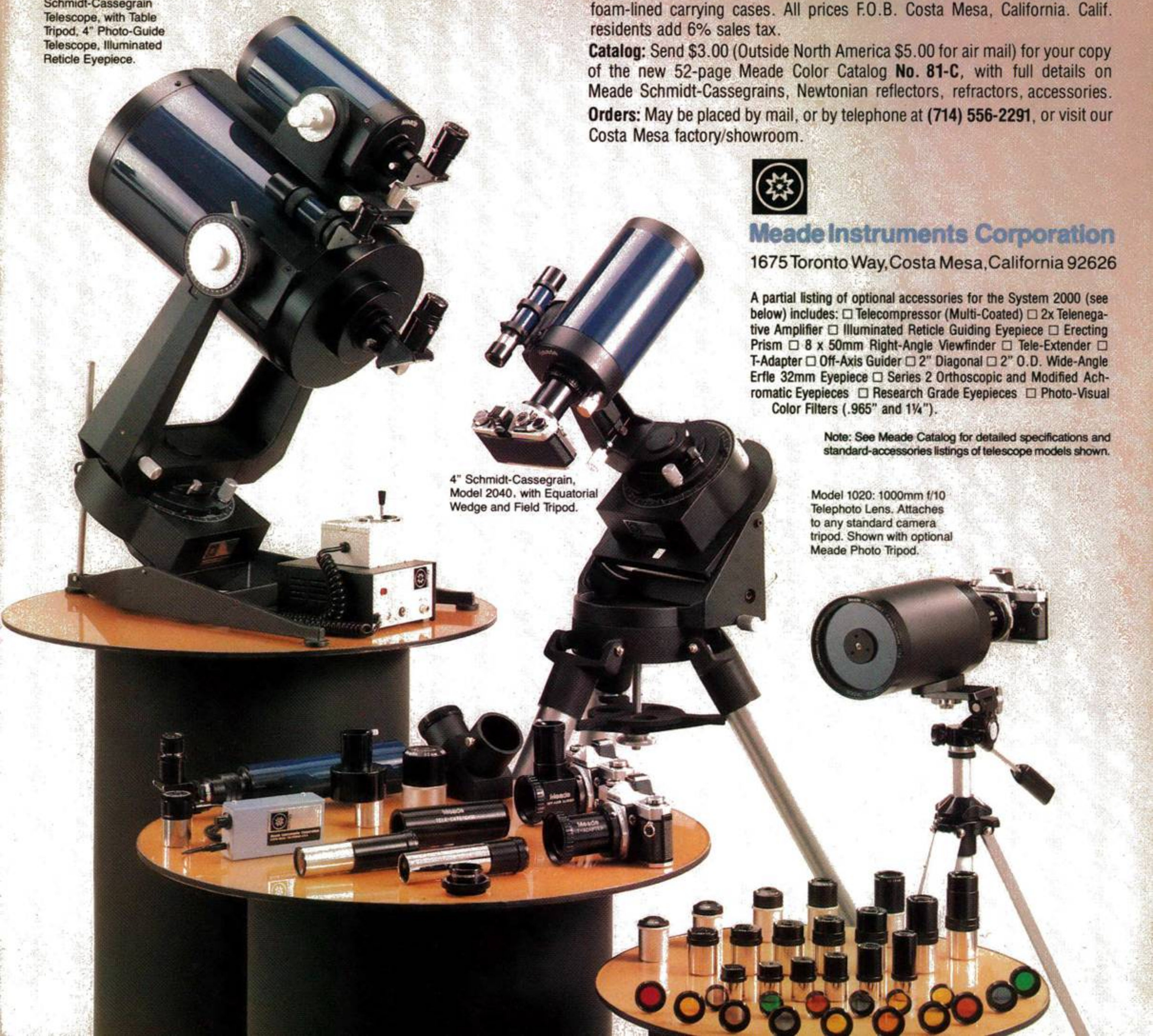
Note: See Meade Catalog for detailed specifications and standard-accessories listings of telescope models shown.



Model 2080: 8" Schmidt-Cassegrain Telescope, with Table Tripod, 4" Photo-Guide Telescope, Illuminated Reticle Eyepiece.

4" Schmidt-Cassegrain, Model 2040, with Equatorial Wedge and Field Tripod.

Model 1020: 1000mm f/10 Telephoto Lens. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.

ASTRONOMY

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6 **The Three Suns of Centaurus**
by Paul Patton

18 **Asteroid Collisions with Earth**
by Richard Teske

Forum **24** **Planetary Scientists Fight Funding Cuts**
An Open Letter to the White House
Voyager: A Sting from Outer Space
by Art Buchwald
A Short-Sighted View of the Solar System

Eye on the Sky **34** **Venus Moves from Evening to Morning Sky**
by Fred Schaaf

In Focus **40**

Behind the Scenes **41**

Gazer's Gazette **43** **Bradfield's Dozen: A Guide to Comet Seeking**
by Ben Mayer

Photography in Astronomy **51** **Making the Most of Black-and-White Astronegatives**
by Dale Lightfoot

Equipment Atlas **58** **Equatorial Platforms**
by Richard Berry

AstroNews **62**

Astronomy Reviews **66**

AstroMart **70**

Stellar Frontiers **74** **Caution! High Winds Beyond This Point**
by Dermott Mullan

The Backyard Astronomer **86** **Lepus**

Cover: Astronomers have long known that our Sun continuously throws off material into space, but our understanding of the processes involved has expanded recently. Stellar Frontiers examines what we now know. This image, taken in calcium K line light in 1929, shows prominences extending above the solar limb. Hale Observatories photograph. These pages: The light of highly ionized atoms, used in this Skylab photograph made in 1974, revealed solar processes hardly suspected a decade earlier. NASA photograph.

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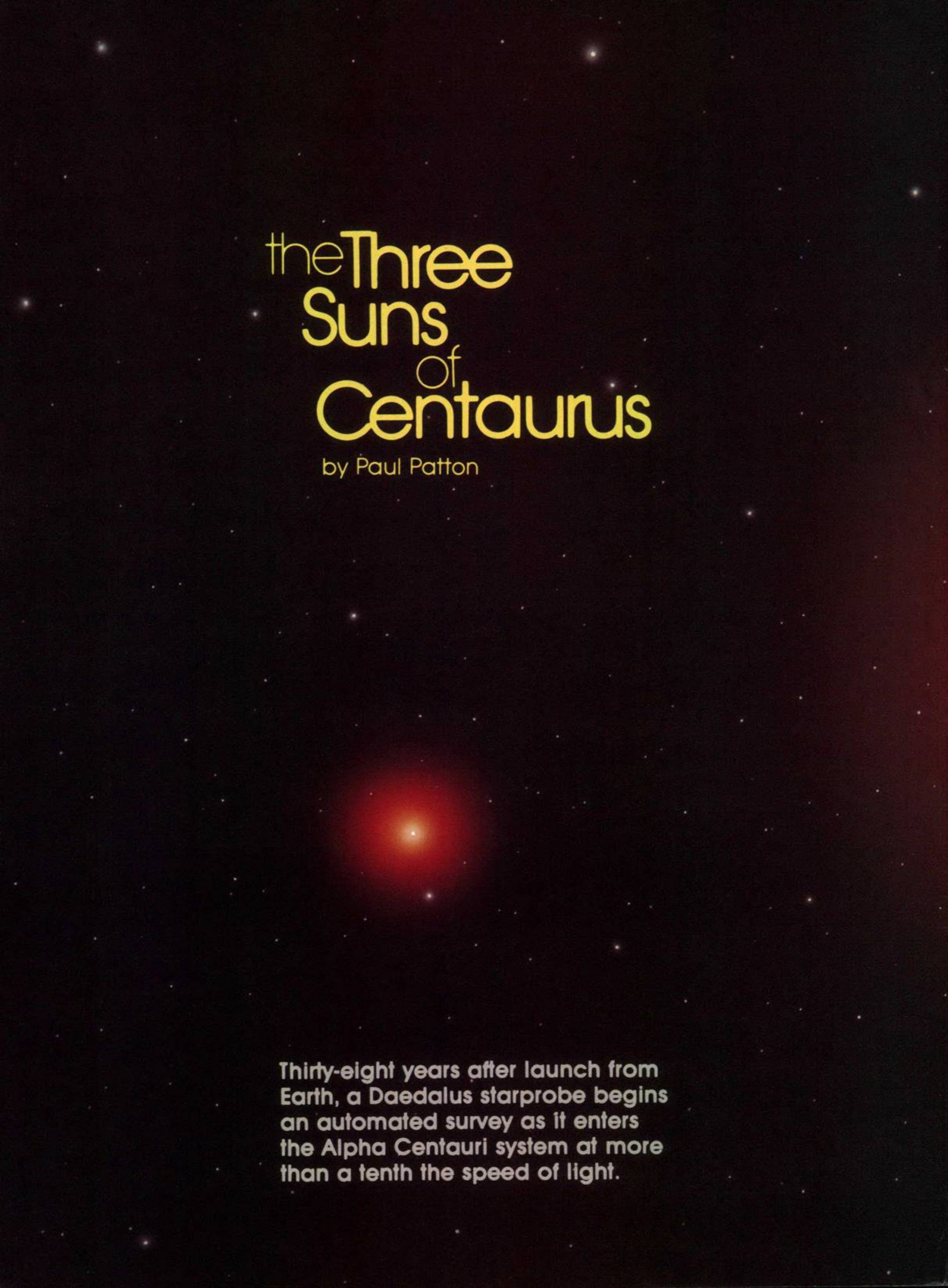


the Three Suns of Centaurus

by Paul Patton

Thirty-eight years after launch from Earth, a Daedalus starprobe begins an automated survey as it enters the Alpha Centauri system at more than a tenth the speed of light.

Painting by Thomas Schroeder

TH

According to ancient Greek legend, strange creatures with the sleek powerful body of a horse and the trunk, arms, and head of a man once roamed northern Greece: they were called centaurs. Most were wild and lawless, but one of them, Chiron, was wise and just. He distinguished himself as a teacher of many famous Greek heroes, including the warrior Achilles. When Chiron died, Zeus, the ruler of the gods, honored him by placing him among the stars.

Later, Greek philosophers no longer took the ancient stories of gods, heroes, and monsters quite so literally. But in about 130 B.C., when Hipparchus of Alexandria mapped the positions of the stars and established most of the constellation names we still use, he remembered the traditional stories of the gods. Thus, today's precisely charted constellations retain the names of mythological Greek heroes and monsters. If you look to the south of Virgo and Hydra, you'll see the constellation Centaurus, named for the honored Chiron.

We now know something very special about the star that marks the centaur's right front hoof. Of all the stars in the sky, none is closer to our Sun than the triple star system we have named Alpha Centauri. In our exploration of the stars, these three suns of Centaurus will undoubtedly be our first port of call. For the present, however, we can only peer at Alpha Centauri across an immense void of empty space; thus our knowledge of it is rudimentary. Earth-based observations can provide only hints of what we might find should we, or our machines, ever cross that void.

Nevertheless, using no more than a good pair of binoculars, an earthly observer can see that Alpha Centauri is really two stars, one of magnitude 0.0, the other of magnitude 1.3. These two stars are called Alpha Centauri A and B, respectively. They revolve around each other under mutual gravitational influence, and complete one cycle every 80 terrestrial years. Their orbits are highly elliptical, so the distance between them varies greatly over the course of one "centaurian" year.

At the point of closest approach, *periastron*, the two stars are separated by about 11 AU — a distance somewhat greater than that from the Sun to Saturn. At the point of farthest separation, *apastron*, they are about 35 AU apart — a distance somewhat greater than Neptune is from the Sun. The average separation between the stars is 23 AU — about the distance from the Sun to Uranus.

If we observe very carefully with our binoculars or a small telescope, we note an 11th magnitude star not far from the Alpha Centauri A, B pair. Measurements show that it, too, is a component of the Alpha Centauri system: Alpha Centauri C. At the present point in its orbit, this small unimpressive star is actually the nearest star to our Sun — thus it is sometimes called Proxima. It orbits more than 1.5 trillion kilometers, or about 10,000 AU from the A and B pair.

As many as four families of planets could revolve within the Alpha Centauri system. In this stylized view, one family circles Alpha Centauri A (bottom left) while another orbits Alpha Centauri B (bottom right). A third revolves around the A-B pair. At top, a fourth family orbits Alpha Centauri C.
Diagram by Thomas L. Hunt.

Of the 50 stars within 16 light-years of our solar system, Alpha Centauri A is most similar to our Sun. Its mass is about 1.08 times that of the Sun and its radius is approximately the same. Intrinsically, Alpha Centauri A is about 1.5 times as bright as the Sun. Astronomers classify both stars as members of spectral class G — stars that shine brightest in the yellow region of the visible light spectrum and have a surface temperature of about 6000 K.

Alpha Centauri B is somewhat smaller and fainter than the Sun. Its mass is 0.88, and its radius about 0.74 times the Sun's — it is only half as bright intrinsically. Alpha Centauri B is a spectral class K star, and is brightest in the orange region of the visible light spectrum. Its surface temperature is about 4000 K.

Dim and ruddy Alpha Centauri C has a mass only 0.12 times that of the Sun or about 100 times that of Jupiter; its radius measures about a third the Sun's, and it is one ten-thousandth as bright. Alpha Centauri C is a spectral class M star. It emits much of its light in the red and infrared portions of the spectrum and has a surface temperature about 2700 K. Although cool by stellar standards, this is the same temperature as boiling iron — 2750 K.

As far as we know, this is the full extent of the Alpha Centauri system. Astrophysical theory tells us the basic properties of the three stars which make up the system, and careful measurements give us a clear picture of their orbits about one another — but these constitute only the "skeleton" of the system. What of its planetary "flesh" — if any? Should each of the three suns of Centaurus be as richly endowed with planets as the Sun, then the Alpha Centauri system must be a fascinating place indeed!

Current ideas on stellar formation suggest that planetary systems may accompany most stars. The star which has a neighborhood we can study in detail — the Sun — obviously possesses such a system. In another sense, three additional planetary systems lie within the scope of our studies. The giant planets, Jupiter, Saturn, and Uranus, each have satellite systems which, in the relative sizes and spacings of their moons, resemble the Sun's family.

Present theories hold that stars coalesce in the gravitational collapse of the tenuous clouds of gas and dust common throughout the spiral arms of our Galaxy. As such a cloud collapses, much of its mass accumulates in a central condensation which becomes a star. The random motions of the dust and gas combine into a rotating, circular motion as the cloud shrinks and condenses. The cloud soon becomes a rapidly spinning flat disk of material that orbits the new-born star. Such disks have been detected by infrared observations of young stars, and astrophysicists think that planetary or stellar companions to a star might form out of such a disk. The exact mechanism, however, remains unknown. As yet, we have no answers on whether planets can form in a multistar system such as Alpha Centauri with its complex gravitational influences.

Stephen Dole of the RAND Corporation has examined the possibility of planets having stable orbits within star systems such as Alpha Centauri's. He found that planets *can* have stable, near-circular orbits about either star in a binary system, provided they orbit so close to their star that its gravitational influence predominates, and the perturbing influence of the other star is minimal. An alternative model allows a planet to orbit sufficiently far from the binary pair that the two stars together act as though they were a single mass. A planet could then pursue a stable orbit around the binary pair's center of gravity. These calculations are simplified because Alpha Centauri C is too small and distant to have a significant influence on planets near Alpha Centauri A or B.

The Alpha Centauri system might conceivably contain as many as four separate planetary systems: one orbiting in Alpha Centauri A's zone of dominance, another in B's somewhat smaller zone, a third circling the A and B pair, and a fourth orbiting remote Alpha Centauri C.

Large, swiftly spinning gas-giant planets like Jupiter, Saturn, Uranus, or Neptune may whirl about in such systems accompanied by retinues of exotic moons. Perhaps magnificent systems of rings surround various planets and glow in the shifting illumination of two suns. Cratered worlds, small and desolate like Mercury and Mars, might dot the system, as well as terrestrial planets cloaked in atmospheres like those of Earth and Venus. On an even more exotic note, classes of planets entirely unknown in our own solar system could populate the Alpha Centauri system.

Both Alpha Centauri A and B are relatively sun-like stars. Could they possess earthlike planets? Might they warm and light worlds with a temperature range that would allow liquid water and complex forms of life?

The region around a star in which a planet can have temperatures consistent with life as we know it is called the star's "ecosphere." Inward of the ecosphere, a planet would be too hot for life. Beyond the outer boundary it would be too cold. But the inner and outer boundaries of an ecosphere — even the Sun's — are not precisely known. We only have estimates of how far inward or outward the Earth could be displaced before it would become too hot or too cold for life. Also, a life-sustaining climate is very complex and does not depend solely on incoming sunlight.

Dole attempted to estimate the limits of the ecosphere. He defined a planet as "habitable for man" if it could support human beings, plants, and animals. Using a highly simplified climate model, he concluded that a planet which receives 0.65 to 1.9 times as much solar energy as the Earth could be habitable if other criteria were also met. Thus, for our Sun, the inner boundary of the ecosphere lies at a distance of about 0.72 AU from the Sun — approximately the orbit of Venus. The ecosphere's outer boundary is at 1.2 AU, halfway between Earth and Mars. Dole's limits may be quite optimistic — but we simply don't know enough about planetary ecospheres to be sure what the real limits are.

Alpha Centauri A, B, and C are all far enough apart that each possesses its own complete

Overleaf: Alpha Centauri C, seen over the desolate craterscape of a moon in its planetary system, is probably too cool to foster life as we know it. But distant Alpha Centauri A and B (right background) may offer far better chances for life. Painting by Michael Carroll.

Measuring the Distance to the Stars

We can see about 6,000 stars with our naked eyes, and Alpha Centauri ranks among the brightest. Only Sirius in the constellation Canis Major and Canopus in Carina are brighter. But the fact that Alpha Centauri is bright does not prove that it is nearby. It might be a moderately bright star seen from nearby — or an extremely bright star seen from a great distance. Deneb, for example, appears just as bright but is 400 times more distant. So how do we estimate the distance to a star?

Astronomers use a relatively simple means of measurement called *parallax*, which employs both geometry and modern measuring instruments. To understand how parallax works, hold your arm straight out and point your index finger at the ceiling. Close your right eye and carefully note the position of your finger in front of the objects on the other side of the room. Now, without moving your head or arm, open your right eye and close your left. Your finger will appear to have shifted against the background. This "movement" is called a parallax shift and happens because each eye sees the finger from a slightly different viewpoint.

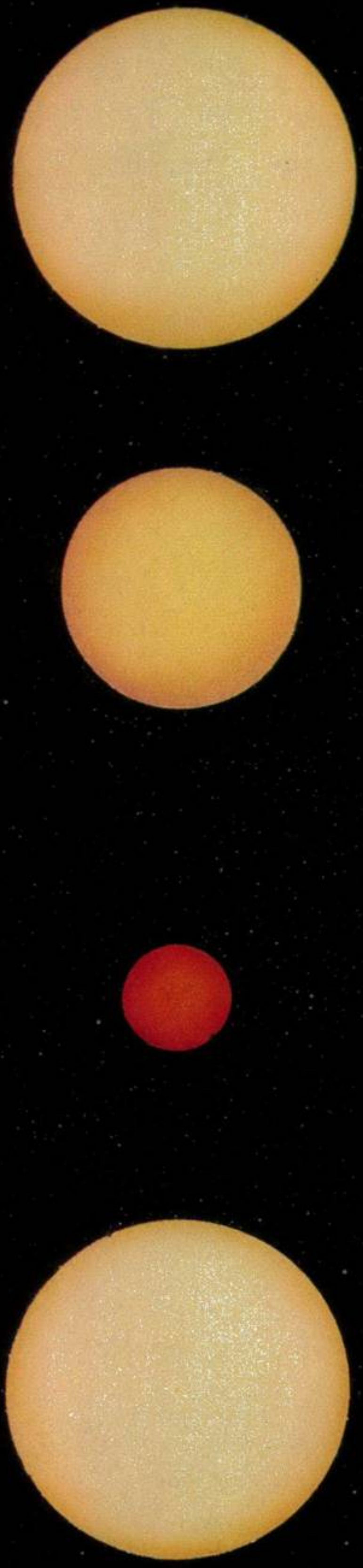
Suppose we expand the process to the celestial sphere and view an object through two telescopes placed in different locations. Using each telescope, astronomers carefully observe the position of the object with respect to the distant background stars. Then they compare the two observations and derive the parallax shift. The greater the parallax shift, the closer the object is. Knowing the distance between the two telescopes, they can calculate the distance to the celestial object from the observed parallax shift.

But the stars are incredibly distant. To obtain a detectable stellar parallax, we need a baseline much longer than even the 13,000 kilometer diameter of Earth. The simplest way of obtaining a much longer baseline is to make the two parallax measurements six months apart. During that time, the Earth journeys halfway around its orbit of the Sun and provides a baseline of about 300 million kilometers.

Over the years, astronomers have measured thousands of stellar parallaxes. None greater than that of Alpha Centauri has ever been found. With its parallax shift of 0.75 second of arc, Alpha Centauri is 40,000,000,000,000 kilometers from Earth.

To reduce these mind-numbing strings of zeros to a more comprehensible form, astronomers employ several very large units of distance. One is the astronomical unit (AU) — the average distance between the Earth and Sun, about 150 million kilometers. Another is the light-year, the distance that light, moving at 300,000 km/sec, travels in one year — about 9½ trillion kilometers. Put into these terms, Alpha Centauri is 270,000 AU, or 4.3 light-years distant.

The Centaurus System



Alpha Centauri A

mass: 2.15×10^{33} grams
1.08 solar masses
radius: 7.3×10^{10} centimeters
luminosity: 1.3 x Sun
absolute magnitude: +4.39
apparent magnitude: -0.04
surface temperature: 6000 K
spectral class: G2 V

Alpha Centauri B

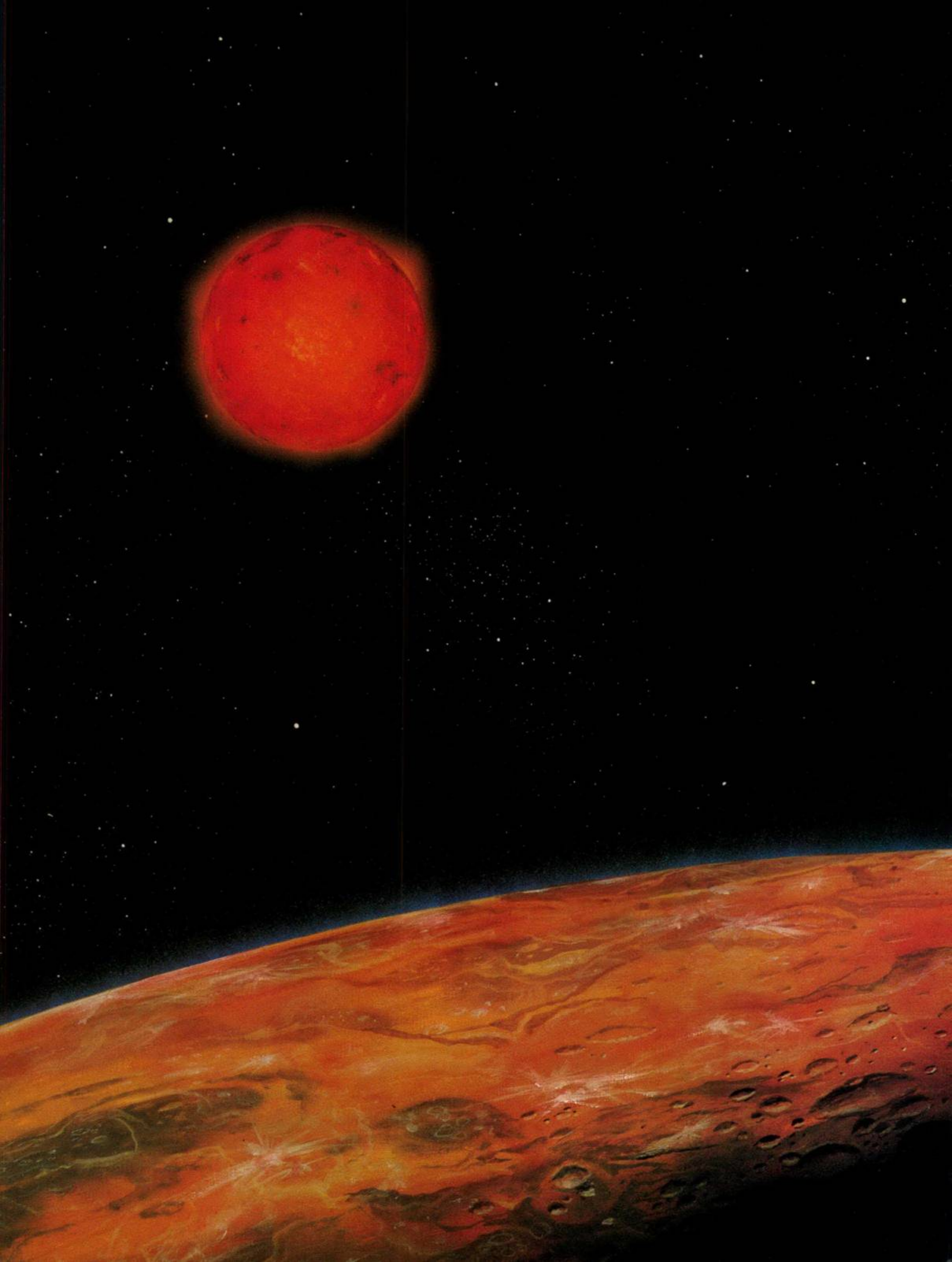
mass: 1.75×10^{33} grams
0.88 solar masses
radius: 5.2×10^{10} cm
luminosity: 0.5 times Sun
absolute magnitude: +5.73
apparent magnitude: +1.33
surface temperature: 4000 K
spectral class: KI V

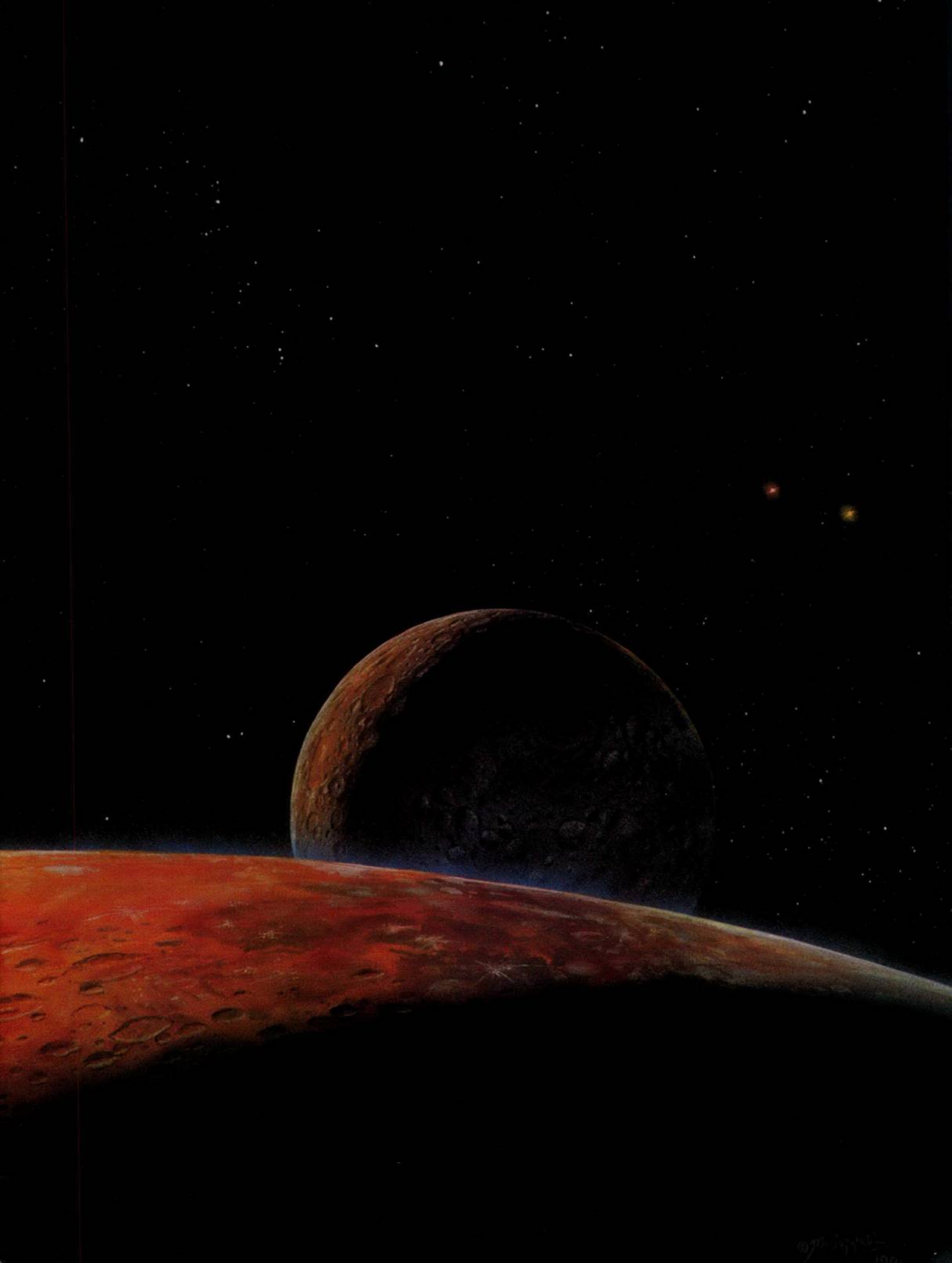
Alpha Centauri C

mass: 2.39×10^{32} grams
0.12 solar masses
radius: 2.3×10^{10} cm
luminosity: $^{1}/_{10,000}$ of the Sun
absolute magnitude: +15.45
apparent magnitude: +11.05
surface temperature: 2700 K
spectral class: M5

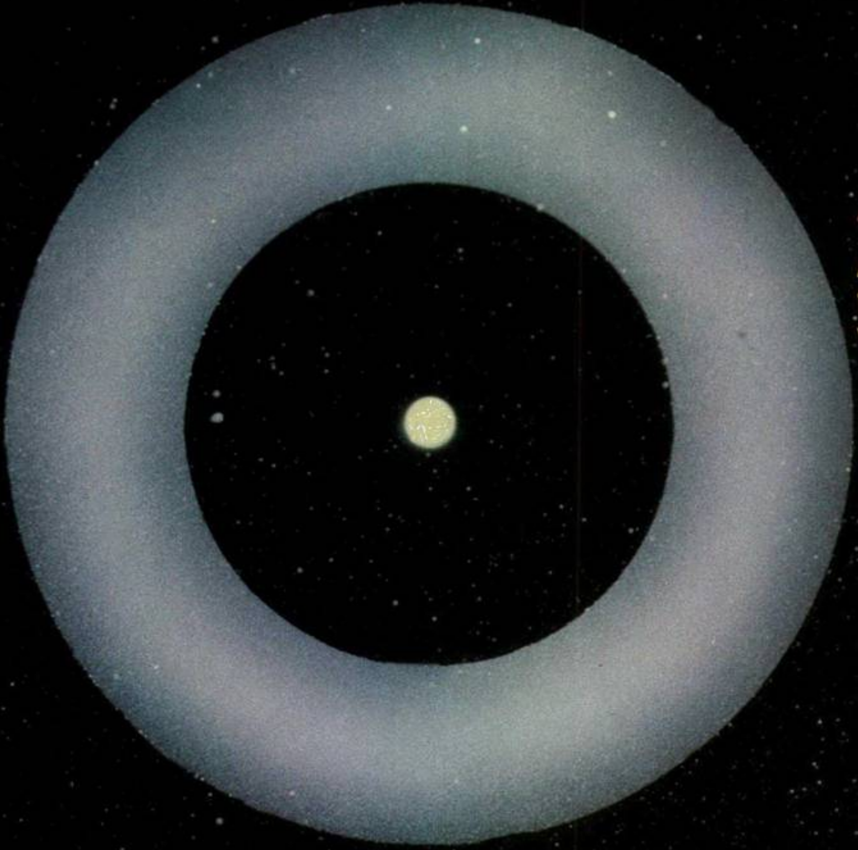
Sun

mass: 1.99×10^{33} grams
radius: 6.9×10^{10} cm
luminosity: 1.00
absolute magnitude: +4.83
apparent magnitude: -26.74
surface temperature: 5770 K
spectral class: G2 V



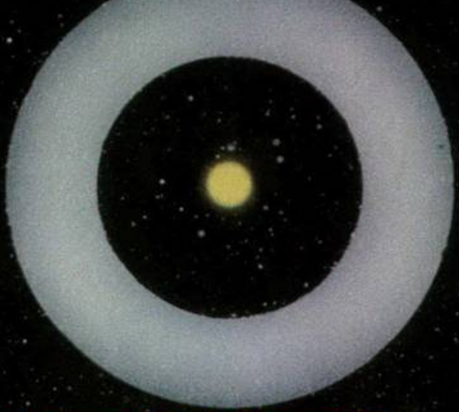


Ecospheres



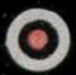
Alpha Centauri A

Alpha Centauri A is slightly hotter than the Sun — its ecosphere is wider and farther out.



Alpha Centauri B

Alpha Centauri B is cooler than the Sun — its ecosphere is narrower and closer in.

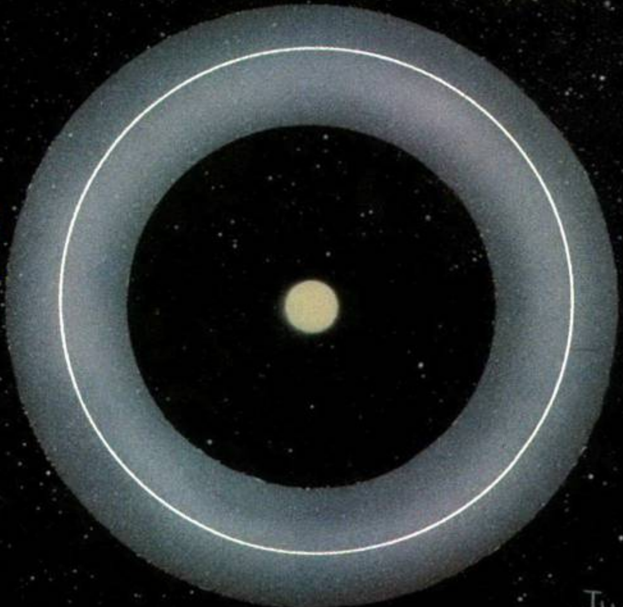


Alpha Centauri C

Alpha Centauri C is very cool — its ecosphere lies close to the star.

Sun

Earth's orbit shows as a white circle.



(Ecospheres are shown to scale, but the four stars have been enlarged 100 times.)

ecosphere, undisturbed by the warming influences of the others. Alpha Centauri A is brighter than our Sun, so its ecosphere is both wider and farther out. Its inner boundary lies at 0.97 AU from the star, its outer at 1.66 AU. If we substituted A for the Sun in our solar system, Earth would be near the zone's inner boundary and Mars near the outer.

Alpha Centauri B is not as bright as Alpha Centauri A or the Sun. Therefore, its ecosphere is narrower and closer in than the Sun's: it lies between 0.52 AU and 0.89 AU from B. Substituting B for the Sun, Venus would lie approximately in the center of the zone. Earth would lie beyond its outer boundary and, like Mars in our solar sytem, would be too cold to support abundant life.

The ecospheres of both A and B lie well within their zones of gravitational predominance, and planets could revolve in stable orbits within the ecosphere of either star. In theory at least, either or both could possess earthlike planets.

Alpha Centauri C sports only a very narrow ecosphere, drawn in close around its feeble fires, and ranging from 0.0075 to 0.013 AU from the star. The inner boundary of its ecosphere is only about three times as far from C as the Moon is from the Earth. The rotation of a planet orbiting so near its star would be *synchronous* with its orbit. Just as the Moon always keeps the same face turned toward Earth, such a planet would always keep the same face toward C. In one hemisphere of the planet, the blood-red star would never leave the sky. In the other, perpetual night would reign: both A and B are too distant and dim to light the nightside landscape more than feebly. Alpha Centauri A would be about as bright as the planet Jupiter in Earth's skies, while B would be somewhat dimmer than Sirius.

The sky would be very different on a hypothetical planet orbiting Alpha Centauri A. From 1.3 AU out, the star would look exactly as bright as the Sun in Earth's sky, but its disk would only be three-fourths as big. Still, A is so sun-like we might not notice the difference immediately.

However, something in the sky of our hypothetical planet would be unknown in the skies of Earth — a second sun. Alpha Centauri B would be a tiny, brilliant, somewhat orangish disk, ranging from a quarter to a fiftieth — depending on its orbital position — the size of the Sun's disk in Earth's sky. Its brightness would vary between a hundredth and a thousandth that of the Sun during each 80-year orbit of the two stars.

At certain times, A and B would appear close together in the skies of the planet. Perhaps A would seemingly swallow B as one star eclipsed the other. About half a planetary year later, A and B would be opposite each other in the sky. When A set, B would rise to command the "night" — with a radiance 60 to 600 times the Full Moon in our terrestrial skies.

On a clear night, after both A and B set, a starry darkness would prevail. The constellations would look nearly the same as we see them from Earth. Compared to the vast scale of interstellar space, the distance between Earth and Alpha Centauri is very small. And what about Proxima? Proxima would appear so dim — 8th magnitude — we'd need binoculars or small telescope to find it. It would differ from other stars only in its slow wander across the heavens — completing one circuit every million years. By comparison, our own Sun, seen in the constellation Cassiopeia, would be one of the brightest stars in the centaurian sky.

But the strangely beautiful skies of an alien planet don't guarantee — or even suggest — life. So it's only natural to ask: Can life as we know it exist on worlds circling these three suns?

Dole feels that a planet in C's ecosphere would be least likely to be habitable because it would be baked on one side and frozen on the other. Carl Sagan, however, cautions against such a conclusion. He points out that atmospheric convection — warm air flowing from the day side to the night side, with cool air returning to be heated again — might moderate the temperature extremes. Also, locked synchronous rotation may not be the inevitable fate of such a planet, particularly when the gravitational influences of other bodies are taken into account. If Sagan's optimistic hypothesis is correct, then the possibility of life remains open for Alpha Centauri C and countless other red dwarf stars throughout the universe.

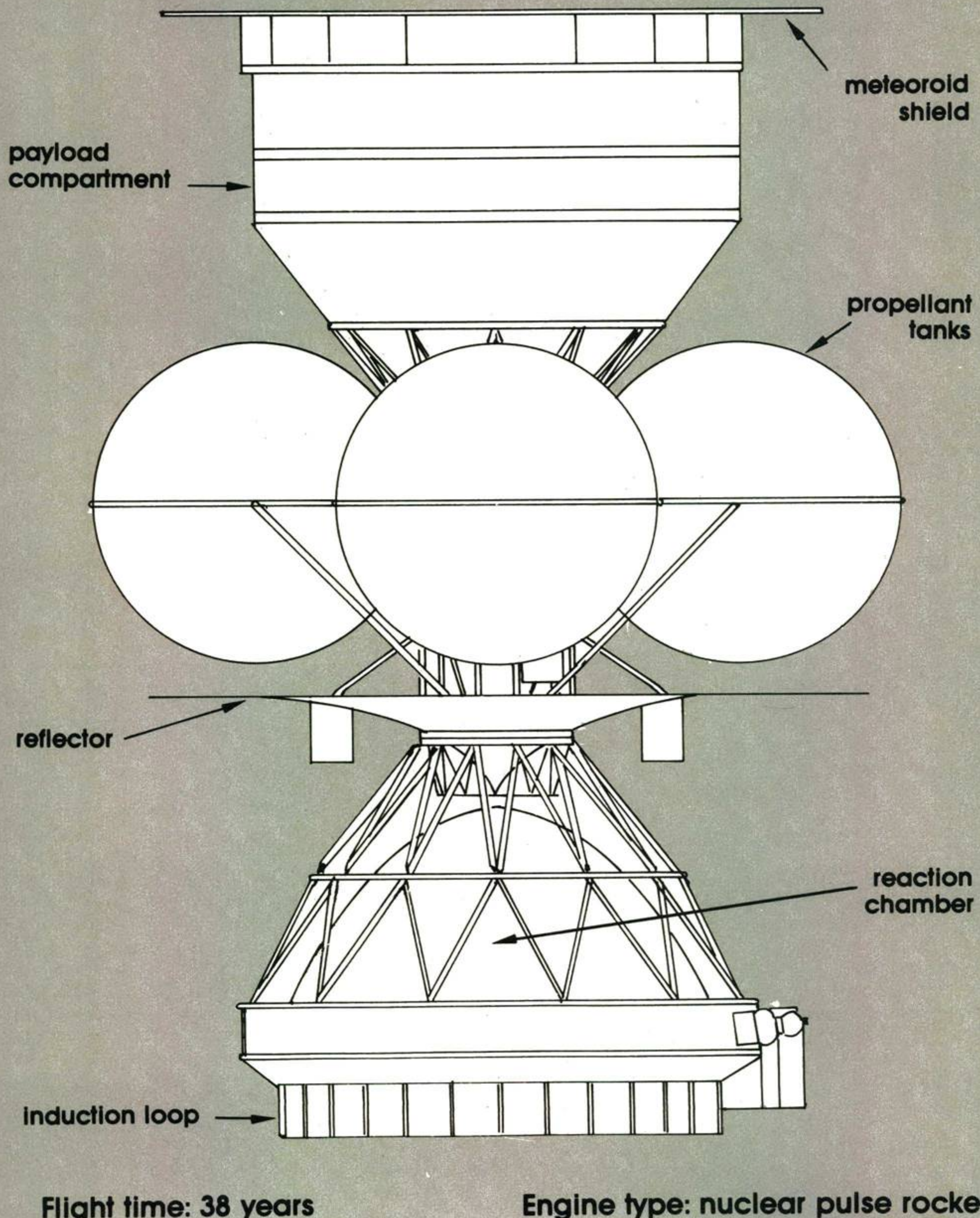
With regard to the A and B pair, let's turn the question around and suppose for a moment that there *is* life as we know it on an earthlike planet somewhere in the Alpha Centauri system. What might it be like? A lot depends on the phrase "as we know it" — which refers only to life forms which, like those on Earth, are composed primarily of carbon, nitrogen, hydrogen, and oxygen. These elements are organized into complex molecules with skeletons of bonded carbon atoms in a solvent medium of liquid water.

Extraterrestrial life probably would not resemble any specific species — houseflies, oak trees, human beings — found on planet Earth. We humans, and the organisms that we live among, are the momentary products of a process of organic evolution that has continued for more than three billion years. Each living species is the product of a vast number of individually unlikely events which may never be repeated. If a species becomes extinct, we will never find it again — even if we search through a billion galaxies. The life forms of each life-bearing planet, at each epoch in its singular history, will be unique to that world and that time.

No one knows whether intelligence is a likely — or even useful — by-product of the evolutionary process. If intelligence can only arise in creatures closely resembling human beings, then it's extremely rare. On the other hand, if there are many evolutionary pathways to intelligence, most planets that have supported life for a sufficiently long period of time may harbor some form of it.

Perhaps the Alpha Centauri system is home to intelligent beings who have not yet developed science and technology — or have possessed it for millennia. Perhaps it is the native soil for a stable civilization with colonies and scientific outposts throughout the system. Or perhaps the three suns of Centaurus shine on the dusty ruins of a dead civilization that long ago perished in war, ecological disaster, climatic change, or some other catastrophe. And perhaps no life or intelligence has ever existed in

The Daedalus Starship


meteoroid shield
payload compartment
propellant tanks
reflector
reaction chamber
induction loop

Flight time: 38 years
Top speed: 12% light speed
Boost period: 4 years
Engine type: nuclear pulse rocket
Propellants: deuterium, helium
Payload mass: 500 tons

the Alpha Centauri system.

Theory and speculation can tell us just so much. Only closer observation will reveal what really exists in distant star systems. Our exploration has just begun, and no one can say where it will lead in the decades and centuries to come. We will have some answers before the end of this decade: by then we should know whether any massive, Jupiter-like planets circle the stars of the Alpha Centauri system. A number of astronomers have already begun work on the problem of detecting the planets of other stars. (See "The Search for Extrasolar Planets," ASTRONOMY, December 1981.)

But to learn the details about other planetary systems, we will have to employ more direct methods. Just as the Pioneer, Mariner, and Voyager spacecraft enriched our knowledge of our own solar system, an automated space probe equipped with cameras and instruments would open the Alpha Centauri system to "first-hand" investigation. Unfortunately, Alpha Centauri is so distant that even our fastest interplanetary spacecraft would take 80,000 years to reach the star. A probe would have to travel much faster than any contemporary propulsion system allows.

The British Interplanetary Society, in its *Project Daedalus* study (see box at right), has attempted to develop a preliminary design for an interstellar probe. It would perform the simplest possible mission, a flyby. The Daedalus starship would be propelled by a rapid succession of small nuclear fusion explosions in the ship's reaction chamber. These explosions would be triggered by high-powered electron beams bombarding nuclear fuel pellets. Soon, we may be able to construct such a propulsion system using the now-foreseeable technology of the early 21st century.

The ship's engine would fire continuously for four years, burning 50,000 tons of fuel and accelerating the automated payload to about 36,000 kilometers per second — 12% the velocity of light. Thirty-eight years after launch, the starship would approach Alpha Centauri. Having scanned the system already and selected its targets, it would deploy a number of instrument probes to closely examine various planets. The fleet, still traveling at 12% light-speed, would race through the system, making a rapid succession of photographs and instrument readings. The findings, radioed back after on-board analysis, would reach Earth more than four years later.

Since the round-trip time for signals would be close to nine years, a probe in the Alpha Centauri system could not be directed from Earth. We will need to develop semi-intelligent computers — smart descendants of the primitive "brains" aboard today's Voyager spacecraft — capable of reprogramming themselves and making complex decisions independently.

Eventually, if we develop still more advanced propulsion systems, or are willing to accept longer transit times, we may send robot ships that can decelerate and explore the Alpha Centauri system in detail from orbits around the stars. These advanced probes might even deploy landers and roving vehicles onto the planets of the system. Perhaps, on some planet within the ecosphere of one of the three suns, they would find life.

Project Daedalus

Project Daedalus is a 192 page paperback report on the design of an interstellar probe. It is available for $15 post-paid from the British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

Our robots might, in service to their distant masters, photograph and sample exotic plants and chase bizarre animals while two suns blaze overhead. Imagine the surprise — or consternation — of intelligent centaurians if a strange machine of metal and glass rolled into their community with its cameras whirring! (Imagine *our* surprise if the reverse were true!)

Sending humans to explore the Alpha Centauri system would be vastly more difficult than sending intelligent machines. Humans would require food, water, oxygen, companionship, and a stimulating environment over the long voyage. We could limit the amount of provisions needed, as well as the size of the spacecraft and its crew, if we could develop very fast spacecraft. Such a spacecraft would need to accelerate massive payloads to nearly the velocity of light and decelerate them again on arrival. A spacecraft that accelerated at 1 g for half the trip and decelerated at 1 g for the other half could reach Alpha Centauri with an elapsed ship-time of less than five years. The astronauts aboard would feel one normal Earth gravity for the entire trip. Unfortunately, such a starship would require titanic quantities of energy, and building it lies far beyond our present-day technology.

As an alternative, we could send a very large but slow spacecraft in which thousands of people, plants, and animals could live for many generations in a closed ecosystem. Creating and maintaining such an ecosystem, however, would be very difficult.

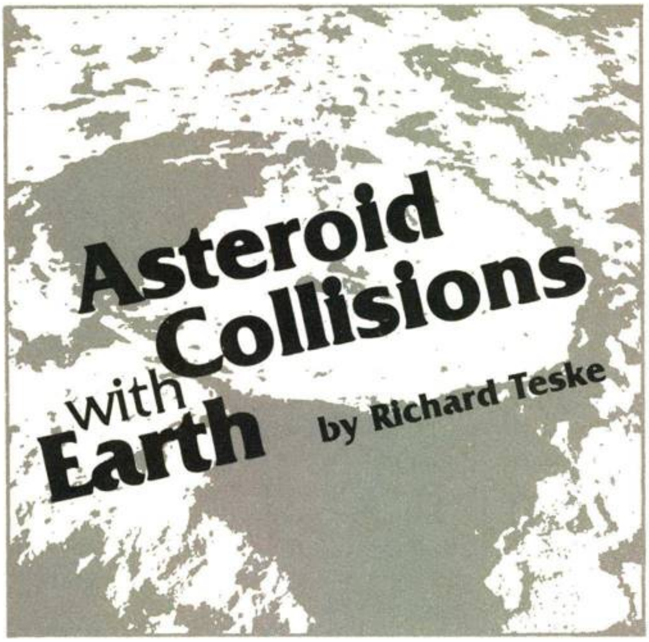
A third option is to place the crew in a state of prolonged hibernation or suspended animation. Then we could send crews on voyages lasting many decades with a minimum of provisioning and living space. Humans might then travel to Alpha Centauri without a very advanced propulsion system or a closed ecosystem. Unfortunately, no one knows how the required state of hibernation might be achieved.

The full exploration of the Alpha Centauri sytem awaits breakthroughs in engineering, ecology, physiology, or cryobiology. In the meantime, the three suns of Centaurus beckon to us across the light-years. The shining point in the front hoof of the Centaur, visible on a clear night in the southern skies, draws our minds outward — though it is but one star system among multitudes. The night sky remains for us what it was for the ancient Greeks — an invitation to imagine unknown worlds and exotic creatures.

Paul Patton recently graduated from the University of Wisconsin-Green Bay with a B.Sc. in physics. He has an avid interest in astronomy and space exploration.

Asteroid Collisions with Earth

by Richard Teske



If any single solar system trait has unified our picture of the planets, it is this: virtually all solid planetary and satellite surfaces are scarred by impact craters. Even on Earth, where erosion rapidly obliterates them, we know of about eighty structures caused by the impact of large extraterrestrial bodies and suspect that about fifty more were created in the same fashion.

And this cratering is not exclusively a relic of our remote past: meteoroids and asteroids capable of massive excavation whirl about in today's solar system. At rare intervals, these bodies encounter the Earth and are "collected" by its gravitational force — often with devastating results. Arriving at speeds from 15 to 30 kilometers per second, an extraterrestrial body a few kilometers in size carries as much kinetic energy as the same volume of pure TNT. In the explosion of such an impact, hundreds of cubic kilometers of rock are pulverized and ejected from the crater, and hundreds more cubic kilometers are melted and fused.

If the colliding body were large enough, such an impact would have worldwide consequences. Dr. Luis W. Alvarez and his colleagues at the University of California, Berkeley, believe they have evidence for a large asteroid impact when the Cretaceous Period became the Tertiary, about 65 million years ago. At this time, a large number of species — including the dinosaurs — suddenly became extinct. Many researchers have claimed that the two events are connected (see "The Fallen Sky," ASTRONOMY, April 1981).

But how could an asteroid impact — a localized event — have wiped out so much life? Let's look at a major piece of evidence, the chemical composition of a thin layer of sedimentary rock.

Scientists base the time scale of geologic history largely on sequences of sedimentary rocks — those deposited underwater — and the fossils they contain. Rocks containing the same or similar fossils were laid down at the same time all over the world. These sedimentary layers accumulated gradually and steadily under the ocean and were pressed into rock by the weight of overlying material deposited on them. The process, called *deposition*, is a slow and steady rain of dead microscopic animals and plants whose remains can be identified easily today.

Geologists now recognize a general sequence of rock layers, and have constructed a relative time scale based partly upon the positions of rocks — usually older beneath younger — and partly upon the fossil life identified in them. They draw distinctions between various periods of geologic time by the easily recognized changes in life forms from level to level in the sediments. But this still leaves one question unanswered: How many years ago did it happen?

In the past few decades, Earth scientists have learned how to tell the actual ages of fossil-bearing sediments by measuring the rate of decay of their radioactive elements. While the relative scale says that the Silurian Period began when the first fishes lived, radioactive dating methods show that this took place about 440 million years ago.

In all, during the entire 570 million years of recorded fossil history, five large and widespread biological extinctions have occurred. Each is indicated geologically by the abrupt absence of certain fossil remains in the sedimentary rock. The most recent extinction, and perhaps the greatest of them, marks the end of the Cretaceous and the beginning of the Tertiary Period. At that time, 65 million years ago, all the dinosaurs, great numbers of reptiles, many marine invertebrates, and nearly all of certain kinds of microscopic floating plants and animals were exterminated. Estimates differ, but possibly half to three-quarters of all species then living were wiped out. Moreover, considerable evidence indicates these extinctions took place all over the world — precipitated by a single event that lasted only a few years.

meteoroids and asteroids capable of massive excavation whirl about in today's solar system

The layer of sedimentary rock deposited at the Cretaceous/Tertiary boundary is recognizable in many locations all over the Earth. The telltale evidence for mass extinction is in the sudden change in fossils seen at the boundary layer. Many species simply vanish.

Alvarez and fellow scientists have made detailed chemical studies of this layer at sites in Italy, Denmark, Spain, and New Zealand. At each location, they found a significant increase in the amount of the rare metal iridium in the thin rock layer that corresponds to

Brimming with molten rock created in the heat of impact, this crater typifies countless others that scarred the surface of Earth early in its history. Though the epoch of heaviest bombardment is long over, a large impact could strike the Earth today with devastating effect. Painting by Bruce Bond.

when the microscopic fossils died out. Above and below this, the iridium concentration has its normal value for Earth's crust. Because the evidence is found all over the world, the contamination must have been global. According to one geologist's work, the iridium-rich layer may have been deposited in 50 years or less.

Because iridium is far less abundant in the Earth's crust than in stony meteorites, some scientists suggest that the enrichment came from an extraterrestrial source. Alvarez and several colleagues think a large meteorite or asteroid supplied the iridium. They calculate that an impacting body about 10 kilometers across would supply the iridium, and suggest that the impact caused a subsequent cataclysm that nearly exterminated all life on Earth.

What effects — immediate and long-term — would this massive impact have? When a large body traveling at tens of kilometers per second suddenly slams to a halt, the kinetic energy of its motion would be released in an explosion with a force roughly equivalent to fifty million megatons of TNT. The asteroid itself would be completely desroyed within one second of impact, and much of its mass would be flashed into incandescent vapor.

A shock wave traveling downward and outward into the surrounding rocks would excavate a 100 kilometer crater in 10 to 15 seconds, spew out broken rock and dust at several kilometers per second, and fracture material far below the crater. Melted rock would flow, and widespread faulting would create a multi-ringed collapse structure like the great ringed basins we see today on the Moon and Mercury.

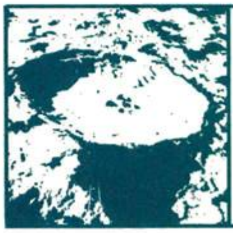
The hammer-blow would also cause a titanic earthquake, devastating everything within a thousand kilometers of the site, and generating a powerful atmospheric blast wave. In less than a minute, an area the size of West Virginia would be broken, shattered, and littered with rubble. Several thousand cubic miles of rock would be ejected from the impact area and thrown high into the air.

an extraterrestrial body a few kilometers in size carries as much kinetic energy as the same volume of pure TNT

But destructive as it would be, the impact itself — explosion, earthquake, and blast wave — would probably not cause any planetwide extinction of life. Rather, the worst damage would be done by the vast quantity of pulverized rock thrown into the stratosphere.

Consider the consequences that followed in the wake of a large — but ordinary — explosive volcanic eruption. In 1815, the Indonesian volcano Tambora erupted with great violence and hurled 100 to 150 cubic kilometers of dust into the air. Apart from the immediate devastation, significant long-term effects appeared. Volcanic dust tinted sunsets and sunrises the world over. The weather in 1816 was so bad it was called "the year without a summer." Certain places in England that summer had only three days without rain. In many places, skies were overcast for months and temperatures were abnormally low.

Researchers calculate that about thirty to forty times more stratospheric dust would result from an asteroidal impact. This would cause a staggering reduction of sunlight — to only a tenth of full moonlight. The shaded days would last many years, virtually halting important plant life processes. Food chains based on the photosynthesis of microscopic plants in the oceans and vegetation on land would be catastrophically disrupted. And the consequences would work their way up the food chain, dooming even those species not directly dependent on photosynthesis.



the worst damage would be done by the vast quantity of pulverized rock thrown into the stratosphere

According to this hypothesis, the gradual settling out of the iridium-enriched stratospheric dust would deposit a layer with the chemical anomalies now seen in the boundary sediments. As full sunlight slowly returned to Earth's surface, continental vegetation would regenerate itself from existing root systems and from seeds and spores. Ocean-dwelling photosynthetic plants from the few remaining species would take even longer to regenerate.

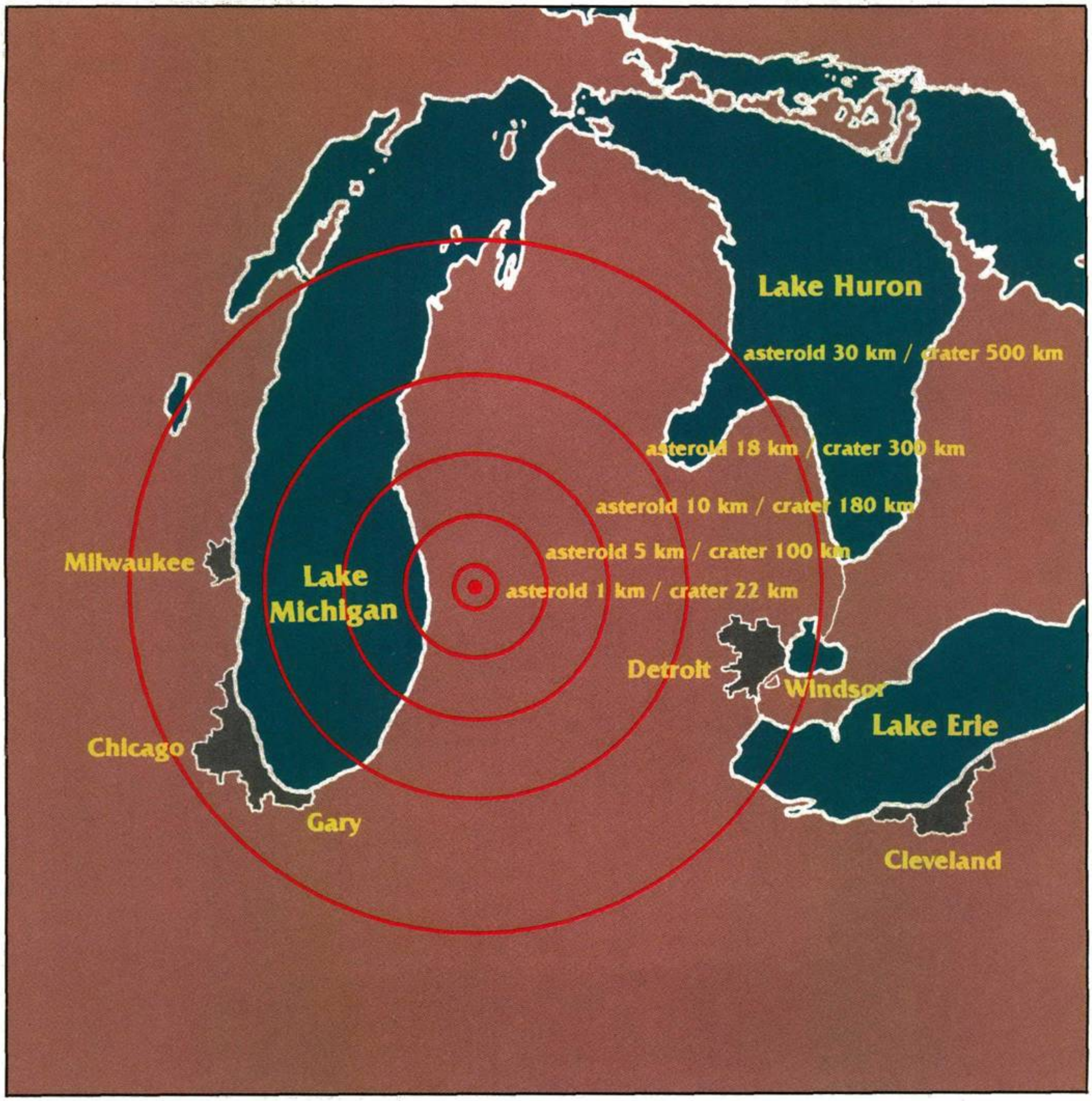
Could dust from the Cretaceous/Tertiary impact have remained aloft in sufficient quantities to choke off photosynthesis? To remain suspended in the stratosphere longer than a short time, dust particles must measure a few tenths of a micron in diameter — about the size of tobacco smoke particles and very efficient at blocking sunlight. Could a large impact disperse particles of this size?

Without a full-scale experiment, scientists can't say for sure, but small, high velocity impacts studied in the laboratory tend to generate very great numbers of tiny fragments. The smaller these particles are, the greater their number. In fact, most of the mass of the fragments ends up in the tiniest pieces.

But massive impacts create more than fragments: another by-product is vaporized rock. Experiments show that the first particles to condense from a gas are of tobacco-smoke size, once again the right size for floating in the stratosphere and blocking light.

But how long will these particles float? Soon after their creation, the tiny dust motes will start colliding with each other and sticking together to form heavier pieces that will sift out of the stratosphere. The more particles there are, the sooner they'll collide, coagulate, and settle to the ground. This natural mechanism clears the stratosphere fairly quickly.

Scientists have noted an additional complication. When volcanic eruptions occur at middle and high latitudes, the circulation of stratospheric winds restricts the dust to regions poleward of 30° latitude, north or south. But dust thrown into the air from low-latitude eruptions such as Tambora in 1815, Krakatoa


Lake Huron
asteroid 30 km / crater 500 km
asteroid 18 km / crater 300 km
asteroid 10 km / crater 180 km
asteroid 5 km / crater 100 km
Milwaukee
Lake Michigan
asteroid 1 km / crater 22 km
Detroit
Windsor
Lake Erie
Chicago
Gary
Cleveland

The concentric rings above show the extent of craters that asteroids — traveling at 25 km/sec and ranging from 1 to 30 kilometers in diameter — would make if they struck Grand Rapids, Michigan. This is the *crater* only; the regions of devastation would spread much wider.

in 1873, and Agung in 1963 spread all over the globe. If an asteroid produced a worldwide dust pall, it probably struck at a low latitude.

It seems at least possible that a substantial quantity of dust could be injected into the stratosphere by a great impact — and it might remain there long enough to do a deadly job of mass extinction. Though the impact hypothesis remains unproven, there's no reason it couldn't have happened — and substantial evidence that indicates it did.

The idea of a large asteroid impact extinguishing a major portion of terrestrial life millions of years ago naturally raises the question of when this might happen again. Putting it more bluntly, are we next?

Though almost all asteroids stay in nearly circular orbits between the paths of Mars and Jupiter, a surprising number of them follow very elliptical orbits that swing inside the Earth's. The motions of these "Earth-crossing" or *Apollo* asteroids (so-named for their prototype) constantly change under the shifting gravitational tug of the planets. This perpetual shuffling of orbits makes it likely that at least some will strike the Earth.

Less than 50 Apollo objects have well-calculated orbits, but Dr. Eugene Shoemaker and his colleagues at Caltech estimate there may be as many as 700 to 1300 Earth-crossers one kilometer across or larger. The biggest known Apollo object has a diameter of 10 kilometers, and Shoemaker estimates that seven to 13 more may also exist.

Several different researchers have worked out the mathematical probability of an Earth/asteroid collision — and their calculations generally agree. A 10-kilometer asteroid will hit the Earth every 100 million years or so, blasting out a crater some 200 kilometers across. Small craters form more frequently, since the smaller objects strike more often. We can expect a crater 10 kilometers in diameter or larger to "appear" about every 100,000 years.

The fact that recorded history goes back only some 10,000 years at most skews our perspective somewhat. We have had no catastrophic impacts since history began, and so we think we're safe. Yet the mathematical probability of an impact in such a short span of geologic time is negligible. We aren't safe — we've just been lucky. The long-term conclusion is inescapable: our planet has been hit in the past and will be again.

What could we do about it? Probably nothing. To start with, we might not even see it coming. Despite the typical scenario in novels, movies, and TV programs — accidental discovery, swift and careful tracking, desperate but finally successful countermeasures — we might not know that an impact was imminent until far too late.

Apollo asteroids are difficult to locate and track — largely because we don't know where to look for them. They are also small and dark — about as reflective as the Moon. There is *some* chance one might be photographed by a large telescope while still millions of kilometers away, but the odds are against it and the object might not be noticed until it was practically upon us.

Although thousands of observatories are located around the world, they scrutinize only a small portion of the sky. For this reason, an oncoming asteroid could go undetected until it is dangerously near us. Even if we spotted the object, we'd have to work fast to see if it was on a collision course.

If a one-kilometer asteroid were detected at tenth magnitude, it would then be only ten times farther away than the Moon. Impact would be five days away, but we wouldn't get five days' warning. Astronomers would have to follow the object for two nights or more before its deadly course became apparent. They would need further observations to predict the impact point. Even fast computers might be yielding that prediction just about the time. . . .

A major U.S. observatory has begun a program to detect faint Apollo asteroids. They use a large aperture, low f/ratio telescope and observing sessions that last several nights. The astronomers do a quick search for asteroids on the plates, following them up and photographing them from night to night. But no one measures the photographs very carefully for high-accuracy positions until the observing session is over. So it seems likely that even this thorough program would not spot a potential impacter ahead of time. A one-kilometer asteroid would become faintly visible to the naked eye in a good dark sky at roughly the distance of the Moon. Few who could see it would give it a second thought, because it would not appear to move appreciably in a few minutes. But if it were coming straight for us, it would arrive in only a few hours and we'd have little time to track it. The ensuing impact on dry land would excavate a 20-kilometer crater — the size of a large city.

we aren't safe — we've just been lucky: our planet has been hit in the past and will be again

If a smaller asteroid were on a collision course with Earth, we probably wouldn't see it until military radar picked it up shortly before impact.

On the other hand, our chance of predicting the arrival of a large asteroid — the kind that may have finished off the dinosaurs — is rather high. A 10-kilometer object could easily be photographed at about the distance of Jupiter. If the orbital path of one of the largest Earth-crossers carried it close enough for a collision with Earth, we would certainly pick it up during one of its missed approaches prior to the final plunge. Unfortunately, this still leaves us the problem of what to do about it.

Strange as it may seem, we can be comforted by the heavily cratered planetary surfaces throughout the solar system — if we keep in mind that such surfaces are 3 to 3½ billion years old. The solar system's heaviest bombardment was early in its history when debris left over from the creation of the planets was swept up by them and scarred their surfaces. Only a remnant of this debris remains; most of it is stored safely in the asteroid belt. The Earth will gather a stray piece from time to time, but the heavy pummelling is long over. And although an asteroid impact would have serious consequences for all of us, they happen far too rarely to seriously concern us.

Richard Teske is a professor of astronomy at the University of Michigan at Ann Arbor. His recent research has been in the field of solar physics.

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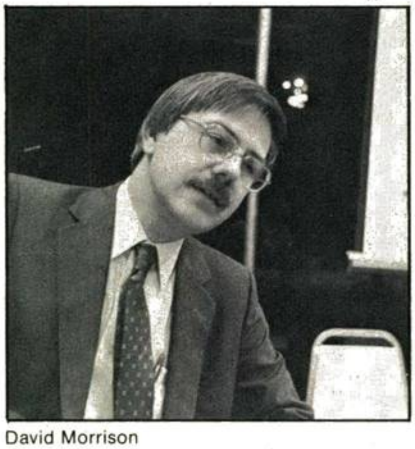
ASTRONOMY FORUM

Planetary Scientists Fight Funding Cuts

It should have been a celebration, coming as it did after the incredible success of the Voyager 2 Saturn flyby. It should have been an occasion for the celebration of twenty years of solar system exploration, a celebration of humankind's first steps into space. It should have been a time of triumph, because the collective human consciousness is now enriched by our knowledge of many new worlds. From all over the United States, planetary astronomers gathered in Pittsburgh to discuss their latest scientific data, to hear what other astronomers were working on, and to report in public the findings of their own previous year's research.

But they were deeply distressed. Only a few weeks earlier, the Reagan Administration had announced another round of cuts from the fiscal year 1982 federal budget. NASA was getting another cut — \$367 million from the FY82 budget and \$1 billion from FY83 and FY84. But no cuts for the Shuttle — the Department of Defense needs it. The rumor — with no assurances coming from NASA higher-ups that it wasn't true — was that the planetary space science program would be cut entirely. Project Voyager could be cut off cold — with no Uranus or Neptune encounters. The Deep Space Network — the giant antennas that receive data from space — would be deactivated. There would be no Galileo mission to Jupiter, no Venus orbiting radar mission. And Halley? — not a chance. "They're not just cutting out programs — they're cutting basic science out of NASA," said one angry scientist. The scientists feared not only for the future of planetary exploration, but for the entire future of basic science — and the loss of America's worldwide technological leadership.

I arrived in Pittsburgh on Monday evening and rode from the airport to the hotel next to Richard Terrile, a member of the Voyager Imaging Team and an expert on Saturn's rings. We talked about the rings, the impending budget cuts, what he might do if there were no more planetary missions. In the hotel lobby, I saw Dick Hoagland, a voluble reporter from Cable News Network. He had been working to rally the press — to get major media science writers from the *New York Times* and the *Christian Science Monitor* to cover this year's DPS. "This is the crossroads," he said. He was full of inside stories about what the OMB might have asked NASA to do and what NASA administrators might have said they were willing to sacrifice. I hoped that the rumors were worse than the reality — as rumors often are.

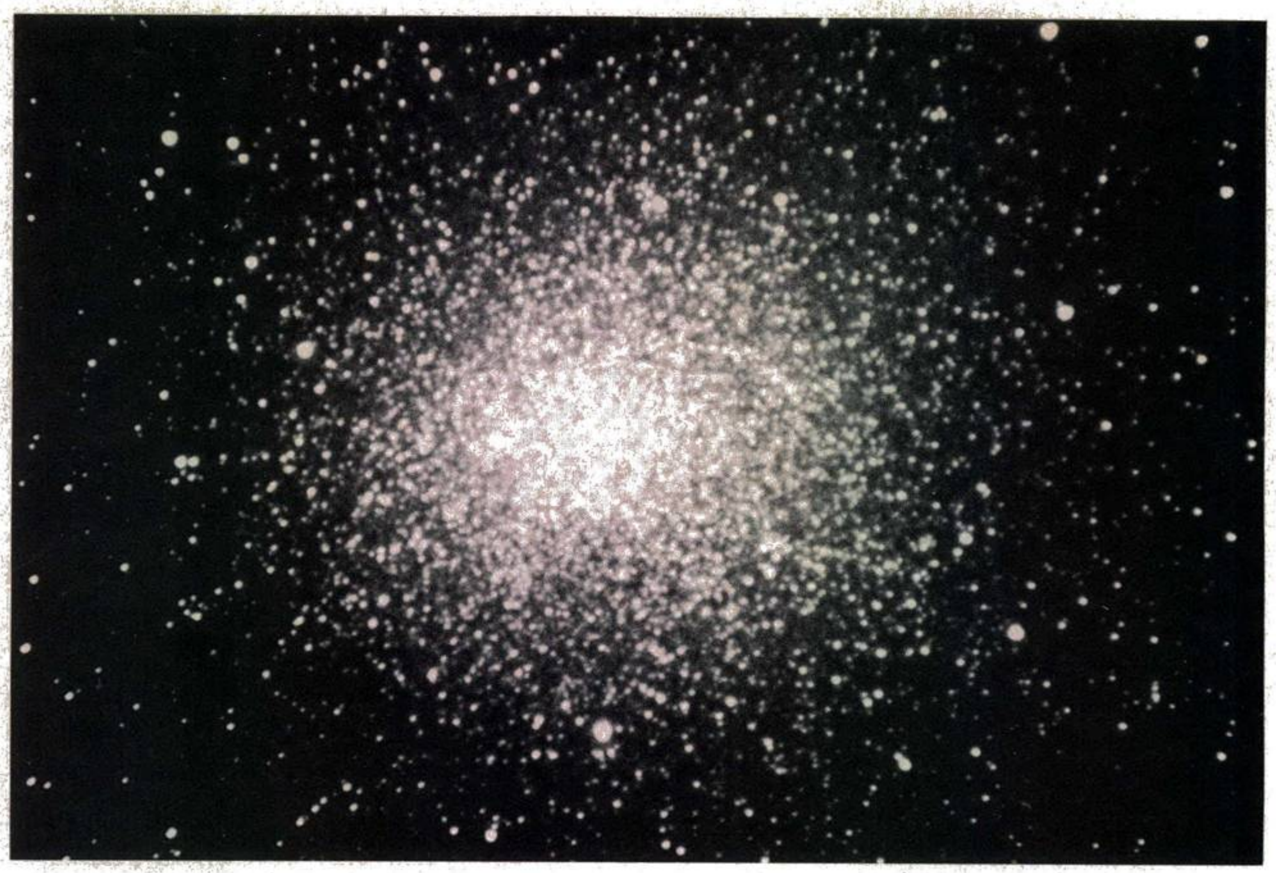


David Morrison

Tuesday began with registration, coffee and donuts, and renewed acquaintances with many scientists who have written for ASTRONOMY over the past few years. Then we all filed into the large meeting room dominated by a huge 1/15-scale model of the Space Shuttle and took our seats while juggling cups of coffee and fat registration packets filled with notes on the glories of Pittsburgh. Tuesday was Voyager day — almost all day devoted to results from the recent flyby of Saturn. I listened intently through paper after paper. Had we gotten our facts right in the Saturn stories in November and December issues? Had the months of analysis since the flyby turned up any new and startling conclusions we hadn't yet heard? As the morning wore on, I felt pretty good about what we'd written.

Several interesting things did come up: the southern hemisphere pattern of atmospheric jets was a near-perfect match for that in the northern hemisphere. To Rita Beebe who reported this finding, it implied that Saturn's atmosphere is not shallow, but is driven by a deeper circulation. She also suggested that Jupiter might show such symmetry if its flows were not so broken up by large white oval storms and the Great Red Spot.

We next heard papers on Titan's atmospheric hydrocarbons and aerosols, then one by John Anderson on the satellites. Voyager 1 data were incomplete, and showed no obvious outward decreasing trend in densities. However, when Voyager 1 data are combined with Voyager 2 data, a general trend appears. The inner satellites, Mimas for example, have densities of roughly 1.4 gm/cm^3, while Iapetus weighs in at about $1.1gm/cm^3$ — consistent with lower temperature volatiles, mainly methane ice, incorporated in satellites farther from hot, primordial Saturn.



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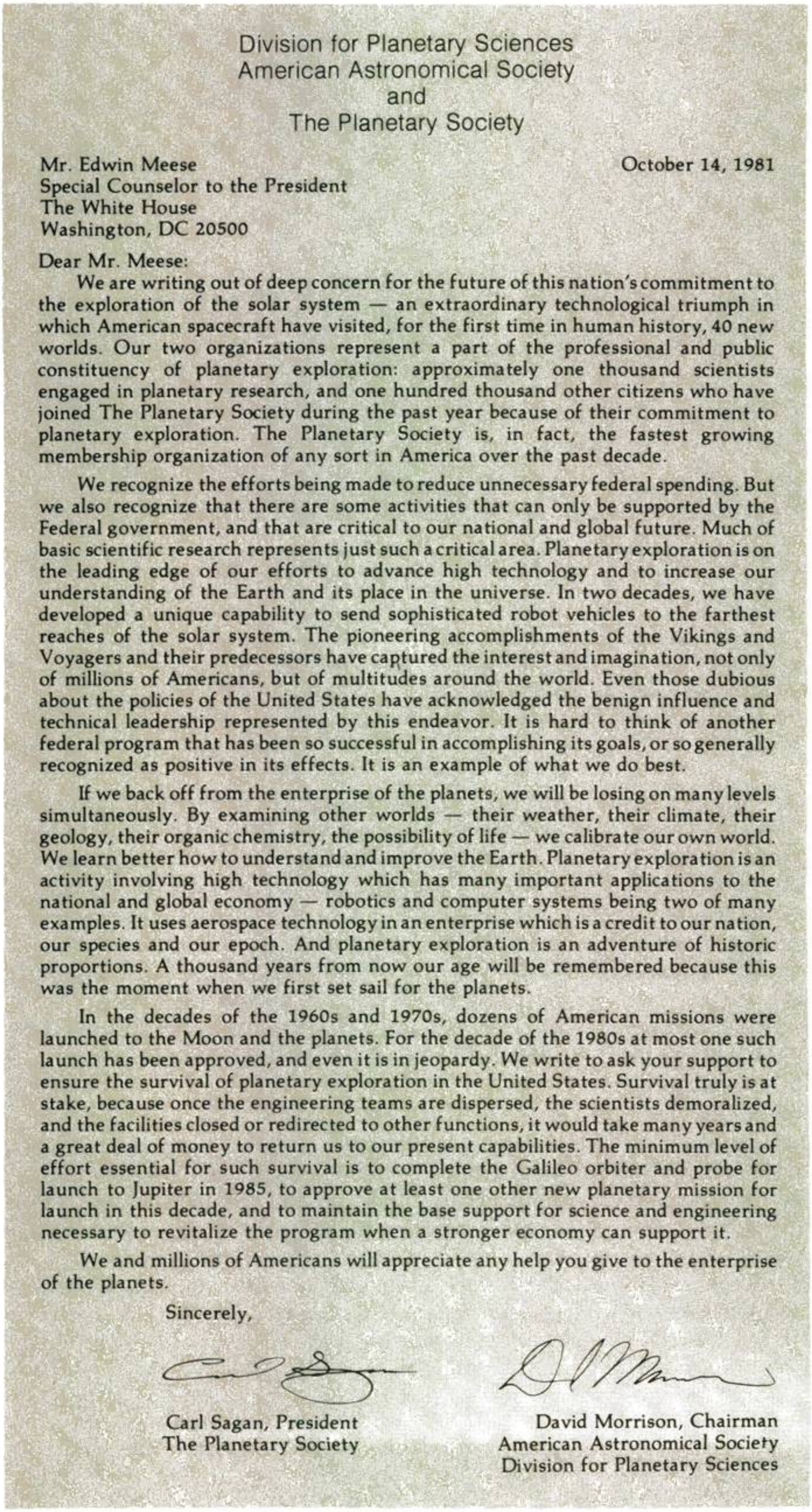
Even after a hurried lunch, I got back to the ongoing papers a little late. I spent the afternoon listening to the details of the shape of the aerosols in Titan's atmosphere (not round), multiple hypotheses to explain the dark side of Iapetus (deposition, erosion, or melting), the possible implications of the satellite density gradient, and why, perhaps, it is not more pronounced. It was strange listening to scientists talk on fascinating discoveries about the "new" worlds in our Solar System made by a spacecraft that might be turned off before it completes its mission. They seemed to find solace in their data.



Division for Planetary Sciences
American Astronomical Society
and
The Planetary Society

Mr. Edwin Meese
Special Counselor to the President
The White House
Washington, DC 20500

October 14, 1981

Dear Mr. Meese:

We are writing out of deep concern for the future of this nation's commitment to the exploration of the solar system — an extraordinary technological triumph in which American spacecraft have visited, for the first time in human history, 40 new worlds. Our two organizations represent a part of the professional and public constituency of planetary exploration: approximately one thousand scientists engaged in planetary research, and one hundred thousand other citizens who have joined The Planetary Society during the past year because of their commitment to planetary exploration. The Planetary Society is, in fact, the fastest growing membership organization of any sort in America over the past decade.

We recognize the efforts being made to reduce unnecessary federal spending. But we also recognize that there are some activities that can only be supported by the Federal government, and that are critical to our national and global future. Much of basic scientific research represents just such a critical area. Planetary exploration is on the leading edge of our efforts to advance high technology and to increase our understanding of the Earth and its place in the universe. In two decades, we have developed a unique capability to send sophisticated robot vehicles to the farthest reaches of the solar system. The pioneering accomplishments of the Vikings and Voyagers and their predecessors have captured the interest and imagination, not only of millions of Americans, but of multitudes around the world. Even those dubious about the policies of the United States have acknowledged the benign influence and technical leadership represented by this endeavor. It is hard to think of another federal program that has been so successful in accomplishing its goals, or so generally recognized as positive in its effects. It is an example of what we do best.

If we back off from the enterprise of the planets, we will be losing on many levels simultaneously. By examining other worlds — their weather, their climate, their geology, their organic chemistry, the possibility of life — we calibrate our own world. We learn better how to understand and improve the Earth. Planetary exploration is an activity involving high technology which has many important applications to the national and global economy — robotics and computer systems being two of many examples. It uses aerospace technology in an enterprise which is a credit to our nation, our species and our epoch. And planetary exploration is an adventure of historic proportions. A thousand years from now our age will be remembered because this was the moment when we first set sail for the planets.

In the decades of the 1960s and 1970s, dozens of American missions were launched to the Moon and the planets. For the decade of the 1980s at most one such launch has been approved, and even it is in jeopardy. We write to ask your support to ensure the survival of planetary exploration in the United States. Survival truly is at stake, because once the engineering teams are dispersed, the scientists demoralized, and the facilities closed or redirected to other functions, it would take many years and a great deal of money to return us to our present capabilities. The minimum level of effort essential for such survival is to complete the Galileo orbiter and probe for launch to Jupiter in 1985, to approve at least one other new planetary mission for launch in this decade, and to maintain the base support for science and engineering necessary to revitalize the program when a stronger economy can support it.

We and millions of Americans will appreciate any help you give to the enterprise of the planets.

Sincerely,

Carl Sagan, President
The Planetary Society

David Morrison, Chairman
American Astronomical Society
Division for Planetary Sciences

The evening public policy program began with a press conference. The speakers looked a bit nervous while TV crews set up their gear and lights. Finally Clark Chapman, who is closely associated with asteroid research, introduced the speakers: David Morrison, Chairman of the DOS, and Carl Sagan, President of the Planetary Society. Morrison led off, "Planetary exploration is important to this country. We should discuss it publicly, examine its role, and insure that it receives serious consideration before there is a severe curtailment of planetary exploration."

Sagan then outlined the role of the Planetary Society: "The Planetary Society itself is an example of the depth of interest of the people of the United States in planetary exploration." It was formed in response to meetings with legislators: "Again and again, we got the response, 'we understand the need for space; it's too bad that the public doesn't.' " So they set out to show that the public did care: "To our surprise," commented Sagan, "today we have 100,000 members, and are the fastest growing organization of any sort in the United States. We think this demonstrates an enormous interest." Add 175,000 ASTRONOMY readers to that, I thought to myself.

Morrison announced that the DPS and Planetary Society were releasing a letter to the White House, "expressing concern that we're ceasing exploring" new worlds, "eviscerating" a major source of national pride.

Questions from the press came thick and fast:

"Won't such budget cuts violate the NASA charter?"

Stofan replied: "The NASA mandate includes the exploration of the Solar System, and, yes, the budget cuts now under consideration would jeopardize the charter it's been asked to follow."

"How real is the threat to Voyager?"

Morrison replied: "I don't know. I do know that it's being discussed."

"How do you explain to a deaf ear — the Reagan Administration — that these cuts are destructive?"

Sagan replied: "I don't know. But we're not in any way special. They're turning a deaf ear to lunches for poor schoolchildren and ongoing education for teachers." As for listening to the public: "I understand that 10,000 letters to Reagan [written by Planetary Society members in favor of space] were boxed, weighed, and turned over to

"SHARPEST I'VE EVER USED"

— Richard Berry
Editor, **ASTRONOMY**

HERE'S THE COMPLETE REVIEW FROM THE AUGUST ISSUE OF **ASTRONOMY**

Plössl Eyepiece Set
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"An eyepiece is an eyepiece — why spend any more than you have to on them?" said a friend of mine when I mentioned I had just purchased a set of Tele-Vue eyepieces. Certainly at $55 each, the price is enough to make anyone stop and think twice. But I am satisfied because the Tele-Vue Plössls are the sharpest I've ever used.

For years I've gotten along with a pretty ratty set of eyepieces, some that I bought 20 years ago, some that came with various telescopes, and a big Erfle I bought a few years ago. I've looked at, and been tempted by, newer ones, but whenever I've compared them at ATM meetings, I haven't seen any that gave sharper images than those I already own.

The Plössls arrived looking beautiful. Nothing was loose; nothing rattled or shook. They were extremely clean and dust-free. For a quick check, I tried all four in my Astroscan — then I knew I had something good! Even with the f/4.5 optical system of the Astroscan, the images were crisp and sharp nearly to the edges of the field. When I focused, the image seemed to "snap" at the moment of best focus instead of mushing through focus as do many eyepieces used on a fast optical system.

I frequently use the Astroscan for projecting the solar image. My trusty old 28mm Kellner eyepiece does a terrible job — the image is mushy and has color fringes. The 28mm RKE is a vast improvement — but it still is a bit soft through focus and some detail is lost. The 26mm Plössl does a superb job — tiny low-contrast details in sunspot penumbrae stand out sharply.

Used with my 12" f/7 telescope, the Plössls deliver crisp images of the planets. I have the distinct impression that the eyepiece adds no optical errors to the image I'm viewing, and that I am seeing everything the mirror can deliver. This is an impression I've never had with any other eyepiece.

Tele-Vue's Plössls also look handsome. They are quite heavy, feel solid, and possess details of fine workmanship. Their shape fits my eye quite comfortably. Although the 26mm can be used with glasses on, I must remove mine to use the others. Without glasses on, I must refocus slightly when I switch from one eyepiece to another. One slight note of caution: the barrels of these eyepieces are *exactly* 1.250" in diameter. Since one focuser I own is undersize by several thousandths of an inch, the Plössls do not fit it properly. If you buy these eyepieces, you may also have to upgrade your focuser.

Are these eyepieces worth their price? If you are using a slow optical system, most eyepieces will give you a satisfactory image. With fast optics, however, I haven't seen anything to match them.

Richard Berry.

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NASA — unread," said Sagan.

Dick Hoagland of CNN asked, "Is the White House asking NASA for a 'political impact statement' to see how much outcry there is?"

Stofan looked uneasy: "These issues are open issues and under discussion," he protested.

"Will you people lose your jobs as a result of these cuts?" asked a local reporter.

Morrison responded, "No. Most of us are employed by universities, and will continue to teach. Those in danger are the young scientists whose careers have not yet started, and for whom the planetary program provides unique opportunities and an inducement to become researchers" — not to mention, I thought, the high school and college students who will see their country turning away from science.

The press conference ended. I stretched and went to get a fresh cup of coffee. The room was rapidly filling with DPS and Planetary Society members, and it was hard to get back to my seat. The panelists assembled, then took their seats.

David Morrison opened the discussion with a few comments of his own: "A certain historic period of exploration has come to an end, and we now have a gap, a good time to reflect on what we've done." Yes, it's the completion of the first twenty years in space. We have visited all the planets of antiquity. But it could be the opening of a new era, the era of more than a first look. "Now, however, we find that under consideration are cuts that would curtail new missions — and even deny us capturing the data from Voyager 2 at Uranus."

Morrison emphasized, "No decision has been made to terminate the planetary program; this is simply one of the prime options in a complex and fluid political situation." Then he warned, "There is a danger that this could become a self-fulfilling prophecy. In some circles it is assumed that the planetary program is *already* over — and that we are cranks who simply do not appreciate the political reality." He ended his presentation with a brief slide show — the great basins of Mercury, the continents of Venus, our landings on Mars, the marble moons and the Great Red Spot of Jupiter, the rings of Saturn now known to be changing from minute to minute and hour to hour, vast geological changes on frozen Enceladus, the clouds of Titan, a terrestrial world in a deep freeze. This audience has heard it all before — yet they break into applause.

Carl Sagan, co-host of the evening's activities, emphasized the humane aspects: "I truly believe we will be envied by future generations for living in the first exciting decades of space exploration. We have the technical capability to do it...all that seems to be lacking is the will to do it. We are now experiencing a decline in the U.S. at a time when other nations are on the incline. It seems a pity that the U.S. — by far the leader — seems ready to back out of this activity." He is, of course, eloquent.

Eugene Levy is, by contrast, angry. He speaks with unexpected force: "As we sit in this room, *not one* of us knows whether the United States will still have a Solar System exploration program next year. Indeed, at the *highest* levels of government, we are told, a decision has not been made whether this country will *continue*...scientific investigation of the planets...or *abandon* our quest to understand the origin of the Solar System, the formation and evolution of planets, the conditions that gave rise to the origin of life, and the varieties and stabilities of planetary environments."

"Now there is nothing wrong, in principle, with this uncertainty... periodic scrutiny is a *good* thing, however, we are *not* faced with an invigorating and open-minded appraisal of where we are...we are *not* seeing an administration eager to assess national scientific programs and committed to moving forward vigorously with those that have particular intellectual, cultural, and national importance.

"Instead, highly placed government officials *assert* that most of the *important* things have already been done! They *announce*, 'the era of planetary investigations is over!' Judgments are being rendered and decisions made without serious study of the issues, without significant consultation...based on uninformed, personal preconceptions. We may see important *policy-level decisions*, affecting major scientific activities in the United States formulated at the *whim* of a few randomly placed people in the administration — people *neither* informed...*nor* sensitive to the importance of science and technology to our society in the large."

Art Buchwald

Voyager: A Sting From Outer Space

I know it doesn't sound important when you measure it against other budget cuts, but NASA is now considering abandoning the Voyager 2 spacecraft which, at this very moment, is on its way to Uranus and Neptune.

The estimated arrival time to Uranus was 1986, and if all went well it was supposed to make a pass at Neptune in 1989.

I happen to be a big fan of Voyager 2 and I know it would break the spacecraft's heart if they cut off all its controls after its magnificent performance to date. To me, it would be a human tragedy. How do you break the news to this magnificent satellite, which is now billions of miles from home?

"Hello, Voyager, this is NASA Control. We are aborting your mission. Do you read us? We are aborting your mission."

"Are you crazy, NASA Control? Everything is going smoothly?"

"You are being riffed for budgetary reasons. Over."

"But my understanding was, when I took this mission, I would get to photograph all the planets. If I don't get to Uranus or Neptune we'll never know what makes them tick."

"We're sorry, Voyager, it's out of our hands. We've decided you're expendable."

"Now you tell me. I'm up here in nowhere barreling away from Saturn and you're going to leave me in the dark."

"Believe us, Voyager, it hurts us more than it hurts you. But David Stockman is adamant. You go out with the school lunches."

"I know what the problem is. You didn't like my pictures of Saturn. But is wasn't my fault. I developed a glitch in one of the movable instrument panels. It could have happened to anybody."

"The pictures you sent back were just great, Voyager. Believe us, we're all very proud of you. But the money isn't there to let you continue on your way."

"I'll go to Uranus and Neptune as a free-lance photographer and it won't cost you a dime."

"It isn't just you that's being riffed. The whole program has to be aborted. We can't afford the ground support to get you to Uranus."

"But where am I going to go? What am I going to do?"

"I guess you're going to have to keep tumbling along. But you can no longer count on any help from us."

"What are we talking about, moneywise?"

"Stockman figures we can save $220 million by canceling your trip."

"That's chicken feed compared to what you people can get out of it. *Playboy* spends more than that to photograph a centerfold."

"Please, Voyager, don't make it harder on us than it is already. If we could have saved the mission we would. A lot of us on Earth are being riffed too."

"Yeah, but you have families to go home to, and you can probably find jobs in military space probes. I'm up here all alone with no one to talk to. If you would just let me get to Uranus, maybe I could get the money from Traveler's Aid to get me back."

"Sorry, Voyager, orders are orders. In 10 seconds we're cutting off all power. You're on your own. Is there anything you want before I press the abort button?"

"Yeah. I want to talk to a priest."

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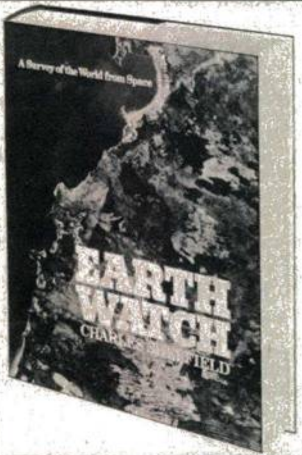
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James Barbato and Elizabeth Ayer

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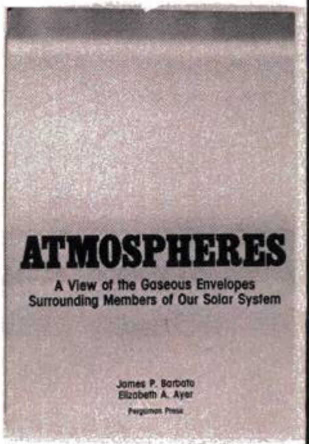
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Levy continued, "We must address ourselves to the premise that the 'era of planetary investigations is over' — to the *excuse*, if you will, that is being floated to justify making the planetary program take the brunt of a budgetary exercise..." I looked at the other panelists. Some listened intently, others shuffled, the next speaker squirmed. Levy spoke at some length on the major problems facing planetary science, concluding, "I believe the assertions that we have finished planetary science, and that we have little left to do that is really important are *indefensible*.... As a nation we do not need to look far to find the money. What we need to look for is the will of an *enlightened* national leadership."

Morrison introduced Andy Stofan as "the highest ranking official in NASA with a responsibility for planetary sciences." I felt a bit sorry for him. Despite the importance of the DPS to NASA programs, neither James Beggs, the NASA Administrator, nor Hans Mark, the Deputy Administrator, were present. Their absence had been taken as a negative "message" from NASA headquarters.

Stofan began on the defensive, explaining NASA thinking: "Much has been blamed on the Space Shuttle — but the real problem is the steady decline over 15 years. We're now at the point where continuing some programs means cutting others. For the FY82 budget, we had a big investment in the Space Telescope and Galileo — so we cut the ISPM."

NASA has four main divisions: the Shuttle, untouchable because of its military role; "applications," which includes Earth resources, communications, and materials processing in space; "aeronautics," or the development of airframes and propulsion systems; and "science," which includes the planetary exploration programs. In the current round of belt-tightening, he said, "NASA can no longer take small cuts across the board — it must consider dropping an entire program element."

It seemed like pretty weak support from the fellow who is the highest ranking NASA official with a responsibility for space science. Stofan concluded, "At worst, we will have to retrench and come back in a few years with a very strong planetary program." It sounded pretty hollow to me.

A Short-Sighted View of the Solar System

We may never see what Uranus, the seventh planet from the Sun, looks like in close up. At least we may not see it for a long time if the U.S. National Aeronautics and Space Administration (NASA) has to turn off the Voyager 2 spacecraft to meet budget cuts demanded by the Office of Management and Budget (OMB). Voyager 2 is now on its way from Saturn, and is due to reach Uranus in 1986. It will then fly on to Neptune in 1989. By abandoning the project and leaving the spacecraft to continue silently on its way, NASA could save $222 million between now and 1989. This is not enough for the OMB which has demanded a $367 million reduction in the space agency's budget in the financial year that began on 1 October. And further cuts of $1 billion a year are threatened for the next two financial years. Such cuts would leave NASA's science program in ruins. Other projects that could feel the pinch include a mission to Jupiter and the Space Telescope, which the space shuttle is supposed to carry into orbit in 1985. The mission to Jupiter, named after Galileo who first turned a telescope on the planet, would involve two spacecraft launched separately: one would plunge into the planet's atmosphere, and one would orbit the planet for 20 months, studying its moons as well.

This mission is the second phase in an overall strategy for planetary exploration; without it the study of Jupiter will end prematurely, negating much of what has already been achieved. The Space Telescope will be able to look at Jupiter — in particular, it will be able to study the planet's weather patterns — but its views of Uranus will reveal about the same detail as will Voyager while still 30 days off its closest approach to the planet. It would be extremely shortsighted of NASA to forego this close look at Uranus on the grounds that the Space Telescope will also look at it; but that is the fear as the agency has already spent some $300 million on the telescope, which is the oldest project awaiting launch.

NASA could save $520 million by dropping both Galileo and Voyager. This may seem like a large sum but it is, after all, $280 million less than Americans spent on chewing gum in 1976, the year the Viking spacecraft landed on Mars. Then NASA's planetary sciences seemed destined for a bright future: now the prospects are dim. Despite the public interest aroused by this year's planetary encounters, the U.S. government seems intent on tearing apart an already watered-down program for the study of the planets of the Solar System. NASA will not be able to reassemble the program when the financial climate improves: neither the planets nor the spacecraft will stand still. By the time Voyager 2 reaches Neptune, Ronald Reagan may be no more than a fading memory for most Americans. Few will remember to blame him for the spacecraft's silence.

— Dr. Christine Sutton, Physical Sciences Editor, *New Scientist* magazine (reprinted by permission of publisher.

Carol Lane, the Senate Science Subcommittee staffer, offered both alarm and hope: "[The Administration, in its efforts to cut budgets,] may dismantle major portions of basic scientific research fundamental to a sustained economic recovery. The decisions being made now have far-reaching implications. . . ." But, she said, "This is not the first serious threat NASA has faced. Nor has NASA's budget been submitted to Congress...[and] Congress has tended to be supportive of space science. While the fate of the space program is unknown, there is support for it in Congress, whether we make use of it or not."

Larry Soderblom described intangibles: "Planetary exploration is the only philosophical spin-off in the federal budget. Over the past four years, we have changed the expectations, the outlook, of educated humanity. Over and over, we have underestimated the complexity of what we would see when we got to the distant parts of the Solar System.

"Exploration," he continued, "is a public process: the common man pressing to know what is there, the scientist wanting to know how. Our robot spacecraft becomes a sensory extension. Through the eyes of Voyager, human beings have traveled a billion miles into space."

He concluded with two questions: "Does NASA recognize the value of planetary exploration?" and "Does the Reagan Administration recognize the value of planetary exploration to the 'man in the street'?"

The final panelist, Voyager Project Scientist Ed Stone, in his uniquely clear and logical manner, spoke on why a nation should explore space at all. First, he said, the quality of a nation is reflected in the quality of the endeavors they feel important. In exploring space, America has shown itself capable of the highest ideals, undertaking challenging projects, and doing what has never been done before. The application of our powerful technologies to peaceful ends is a good thing in itself. Next, he said, it's nice to enjoy a success sometimes, and the space program has been highly successful in a time when many other federal programs have been less so. It reinforces our pride in our nation. Third, the space program is a major motivator of young people — and not necessarily just into science. It represents a future they can embrace with optimism, something that they can look to with pride. Finally, the U.S. cannot decide alone whether space science will end. "We are not," he said, "the only ones in

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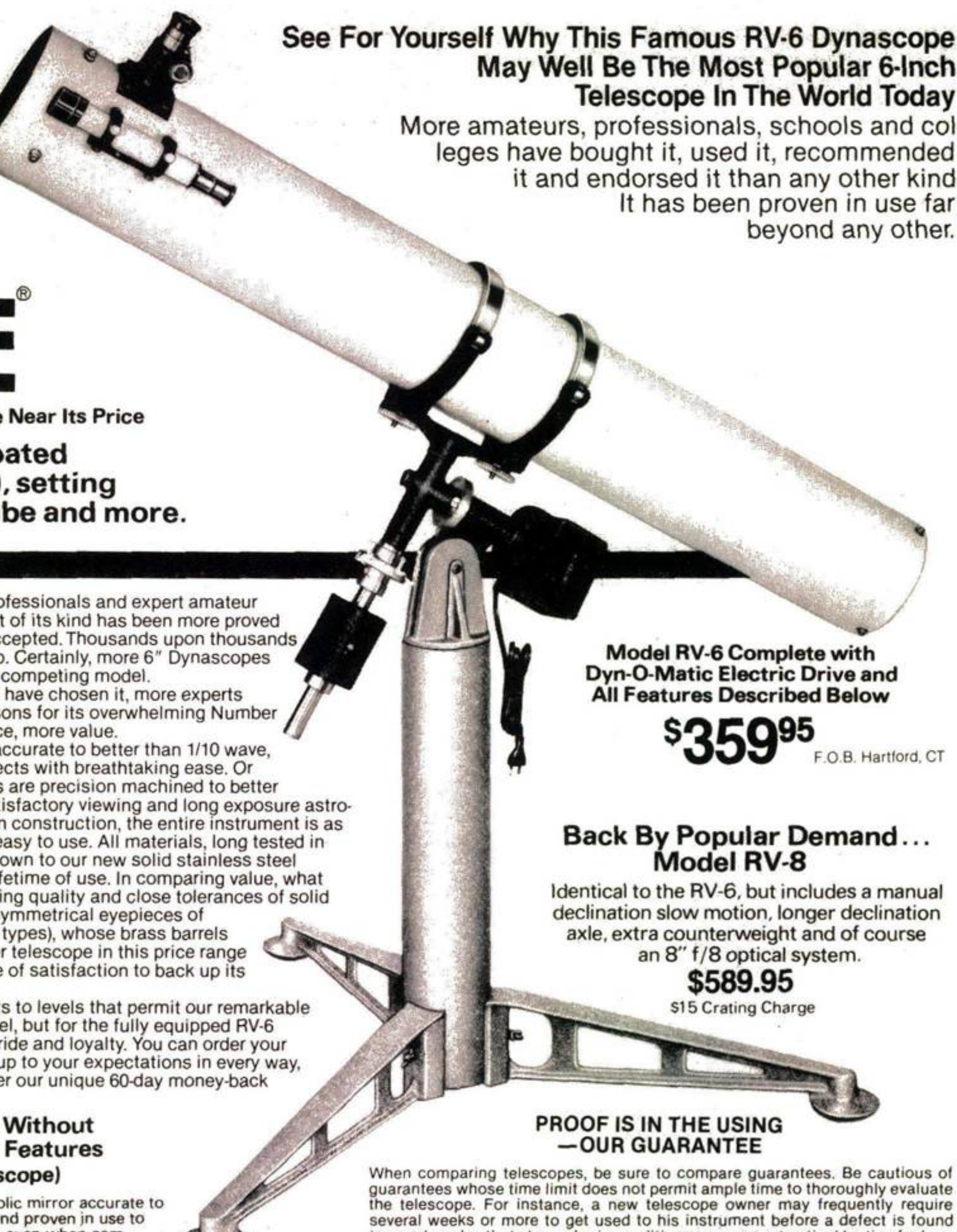

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this game." The U.S. has been the leader, but it cannot set the pace "...any more than the Amercian auto manufacturers could control the pace at which Americans switched to small cars."

Members of the audience then stood to voice their thoughts. "Can we put this enterprise on hold, or will the community dissolve?"

Carol Lane answered: "The budget cutters are simply not aware of the infrastructure that supports these programs." She felt, however, that the Senate Subcommittee on Science, Technology and Space was far more aware of how the cuts would disband not only the scientific community, but also the groups of highly innovative technical people that support it.

Carl Pilcher appealed to the scientists not to give up, "The fight is not lost. We have no friend in the White House. We have few friends in NASA. Andy's superiors are actively working to bring about our demise. The most effective forum is to express your concern to your own Congressmen."

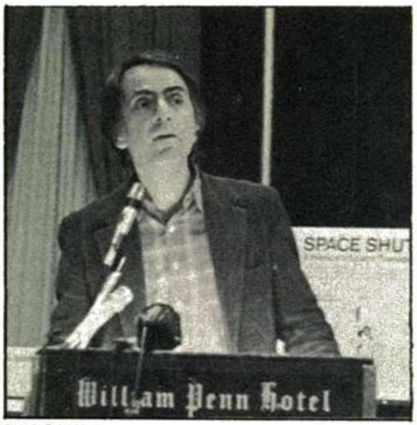
Stofan responded, "Beggs and Mark are trying to fit priorities into a tightly constrained budget. Personally, I think it's a mistake to say we have no support inside NASA."

Carol Lane added, "You *must* approach your Congressman. Maybe you see the groundswell of public support, but they *don't* see it in Washington."

"Stofan said earlier that the support is not perceived," said Hoagland, "but the members of the press I talked to hadn't known of the crisis — so you can be sure that the public hasn't heard of it yet. It isn't that you lack supporters, but that you lack informed supporters."

"Those in power have one agenda — and that one agenda is of such overriding concern that everything else is secondary," said Gene Levy. "Science — basic non-military research — is being decimated across the country."

It was getting quite late, so the meeting broke up. The papers — many of them on the formation of the Solar System — began the next morning at 8:30. We heard about low-mass solar nebulae, high-mass solar nebulae, the Uranus/Neptune problem, the comet clouds far from the Sun. We heard estimates of the number of faint comets far larger than anybody has dared predict in the past, and tantalizing observational evidence supporting those estimates. In the evening, after a fascinating talk on Mayan astronomy, the DPS business meeting began. Tuesday night had been discussion. Wednesday night was business.



Carl Sagan

Mike Belton, a Kitt Peak astronomer and the 1982 chairman of the DPS, opened the meeting: "I intend," he said, "to lead the DPS in a fight to defend and promote the planetary sciences."

Belton made it clear that he intended to go beyond this budget crisis and create support for planetary exploration on a long term basis. "I've heard it said that this retrenchment is temporary," he said, "but it may not be." The DPS, and all supporters of planetary exploration must become involved in a long program of generating political support for it. "We must approach the leaders of all the branches of science; we must enlist their help; we must speak repeatedly with our elected representatives."

Carl Pilcher agreed. "We, as scientists, haven't kept up with politics as we should have. Now we must. We are competing for dollars in a political arena. Good reasons [for supporting space] are not enough. We can no longer afford the intellectual luxury of regarding 'lobbying' as a dirty word."

Bob Nelson of JPL spoke next, "I suggest that we form a political action committee, a committee which actively engages itself in the election process. We must seek professional political help."

Many scientists disagreed, saying that a lobby might impinge on their professionalism as scientists, or that there would no time left for science after the politicking. Carl Sagan responded: "I see a bit of an ivory tower attitude. Our professionalism is the reason we must take action — if this organization is not going to go all-out in support of space science, then who is?"

Mike Belton raised a concern that had already been touched several times: "What are the ethics of sending spacecraft to other planets when people here on Earth are starving? I don't have an answer. It's a question that we must address." Other scientists echoed their concerns that world hunger and nuclear weapons were perhaps overriding problems.

It was Ed Stone who took a broad view, "It's important," he said, "that a nation feed, clothe, and defend its citizens. But a great nation must do more to insure its greatness. Nor is it in a nation's interests to solve all problems relating to these major goals before addressing any other concerns. We should advocate not only those goals, but also advocate activities that will insure our nation's greatness."

Still, he did not carry the argument to its logical conclusion. As part of its role in defending the populace — a well-established and generally accepted role of government — we must also defend ourselves against the effects of pollution, the depletion of resources, and climate changes. Our defense lies in understanding our planet and its processes, and we gain a better understanding of Earth through a knowledge of other worlds. It's cheap, too; NASA gets only 1% of the federal budget, and planetary gets only 3% of NASA's 1% — or 0.03%. Compare that to the 27% of the FY82 budget the Department of Defense will get.

After more discussion, the DPS passed a motion authorizing Belton to develop an action program for the DPS. Belton and his committee would clearly be busy in the weeks following the DPS meeting — attempting to influence budget decisions that might be made as early as November.

Two days later, on the *limousine* back to the airport, I sat next to Carl Pilcher, now on his way to Washington to meet his Congressman. "Congress is the only avenue we have. The Administration is a closed system. They don't respond to lobbying. But even if NASA saves Voyager and Galileo, it's not enough." He worried that organizations such as the Jet Propulsion Lab would cease to be national centers of excellence, with capabilities envied around the world.

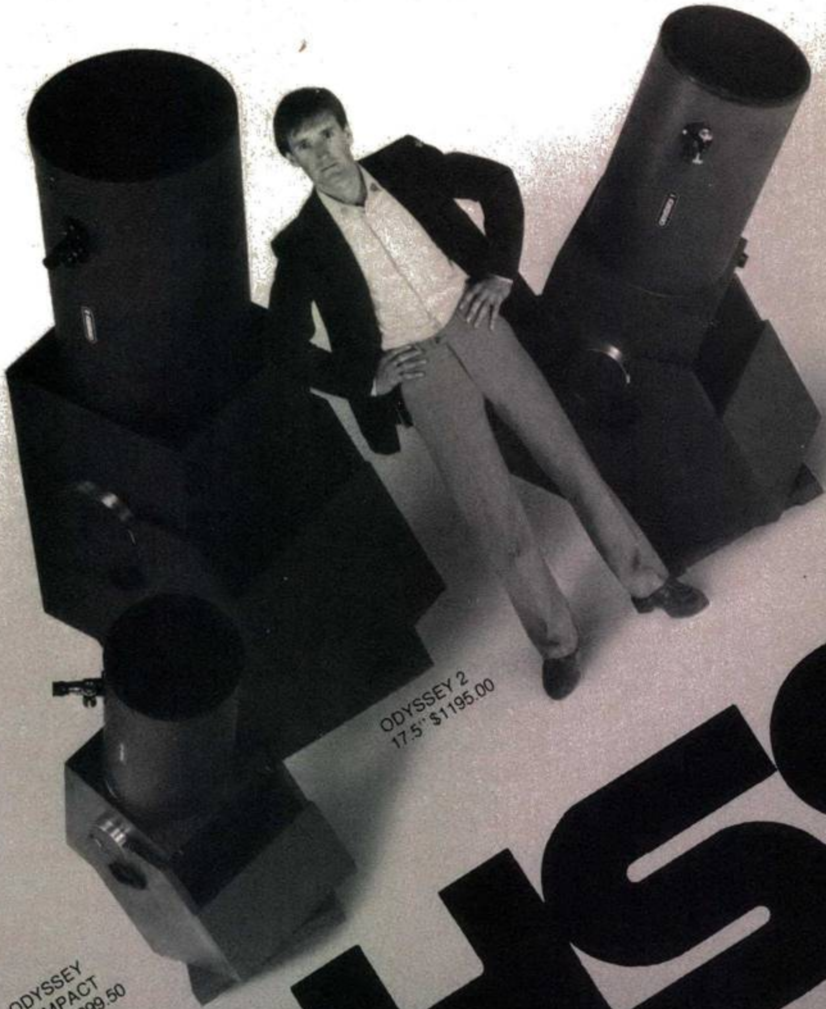
"Are you going to write about this meeting?" he said.

I said I would, but that our December issue was already finished with only one mention of the budgets cuts — in AstroNews. The earliest we could do anything was in the January issue.

"These budget cuts must be approved by Congress — that'll be January or February and it might drag on longer. January isn't too late for them to write."

"I'll tell them that."

— *Richard Berry*



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eye on the sky

venus moves from evening to morning sky

by Fred Schaaf

the wanderers

The striking passage of Venus from evening to morning sky, a line of brightening planets rising in the middle of the night, and several fine conjunctions combine to make January an interesting month for naked-eye skywatchers.

Venus is still favorably placed on the first evening of the year, setting more than two hours after the Sun at 40° N., and standing at an elongation of almost 30°. Venus' distinct crescent shape is striking in small instruments at low magnification. Go out around sunset on a calm evening with good seeing and try to resolve Venus' shape in a 2x or 3x finderscope or weak field glasses — either mounted or held steadily. To steady yourself, sit down or lean against a tree or building.

Can you detect the long, skinny Venus-crescent with your unaided eye? It is possible, but there is no record yet of anyone accomplishing this feat.

On January 9, Venus shines at -3.9 magnitude when **Mercury** overtakes it 5.5° south of Venus. At that time, Mercury is a bright -0.7 and is nearing its greatest elongation of 18.8° on the 16th. Mercury will be visible to the naked eye for several weeks during this apparition. But right after greatest elongation, it falls rapidly to reach inferior conjunction on January 31.

Venus, too, is descending rapidly, following Mercury's path. After its conjunction with Mercury, our sister planet fades quickly, sets noticeably earlier every night, and finally reaches inferior conjunction on the 20th. About 10 hours before this, Venus is only 0.268 A.U. from Earth — closer than any other body except the Moon until January 1990. At what point in their orbits do these planets come closest?

Earth is at perihelion on January 4, Venus on January 27, Mercury on the evening of the 22nd, and minor planet Vesta on the 20th. This is certainly a month for perihelia!

A few years ago, Joseph Ashbrook suggested the use of the old term "combust" for indicating when a celestial object is too close to the Sun to be seen with the naked eye. How long will Venus combust for you? The planet will actually pass $6^1/_3$° north of the Sun at inferior conjunction — this will help northern observers. But Venus and the Sun are far south in the zodiac, so viewers in the southern hemisphere are most favored. After the opening nights of January, Venus will be a difficult object to spot in the evening sky until next year. In February, Venus will zoom up high in the morning sky and reach a magnitude of -4.5, its greatest for 1982.

These last few years have been spectacular for observers who watch the outer planets, providing triple conjunctions of Mars-Jupiter and Jupiter-Saturn in 1980 and 1981. Each of these is a once-in-a-lifetime event, so it is extremely rare that they occurred in back to back years. As 1982 begins, **Mars** closes in on **Saturn** as the two approach opposition. Will a third triple conjunction occur within three years? Almost. Watch Mars move closer to Saturn in Virgo. When does the red planet halt and begin to retrograde away from the ringed planet?

Mars has a triple conjunction this year with 2.9 magnitude Gamma (γ) Virginis. The first of these occurs on January 8 when the 0.8 magnitude planet is little more than one third of a degree from the star. On the same night, Saturn has the first of its three conjunctions with bright Spica. Unfortunately, this pairing (like the two to come) is hardly a close one, since Saturn is almost 5° north of the star. The predicted magnitude of Saturn at the Spica conjunction is 0.9 — what is your estimate?

About 1½ hours after Saturn makes its near-midnight rise, **Jupiter** ascends, brightening slowly from -1.4 magnitude as it passes from Virgo into Libra. Jupiter will pass close to Alpha Librae in October.

Mars is at aphelion — 1.66 A.U. from the Sun — on January 12, and will reach perihelion on December 21. 1982 is one of the rare years in which both of these martian events occur.

On a similar note, 1982 will be the only year in the next 503 that will feature three total eclipses of the **Moon**. The first of these takes place on January 9, but won't be visible from the United States. The next two, in early July and late December, will be. The July totality will be extremely long.

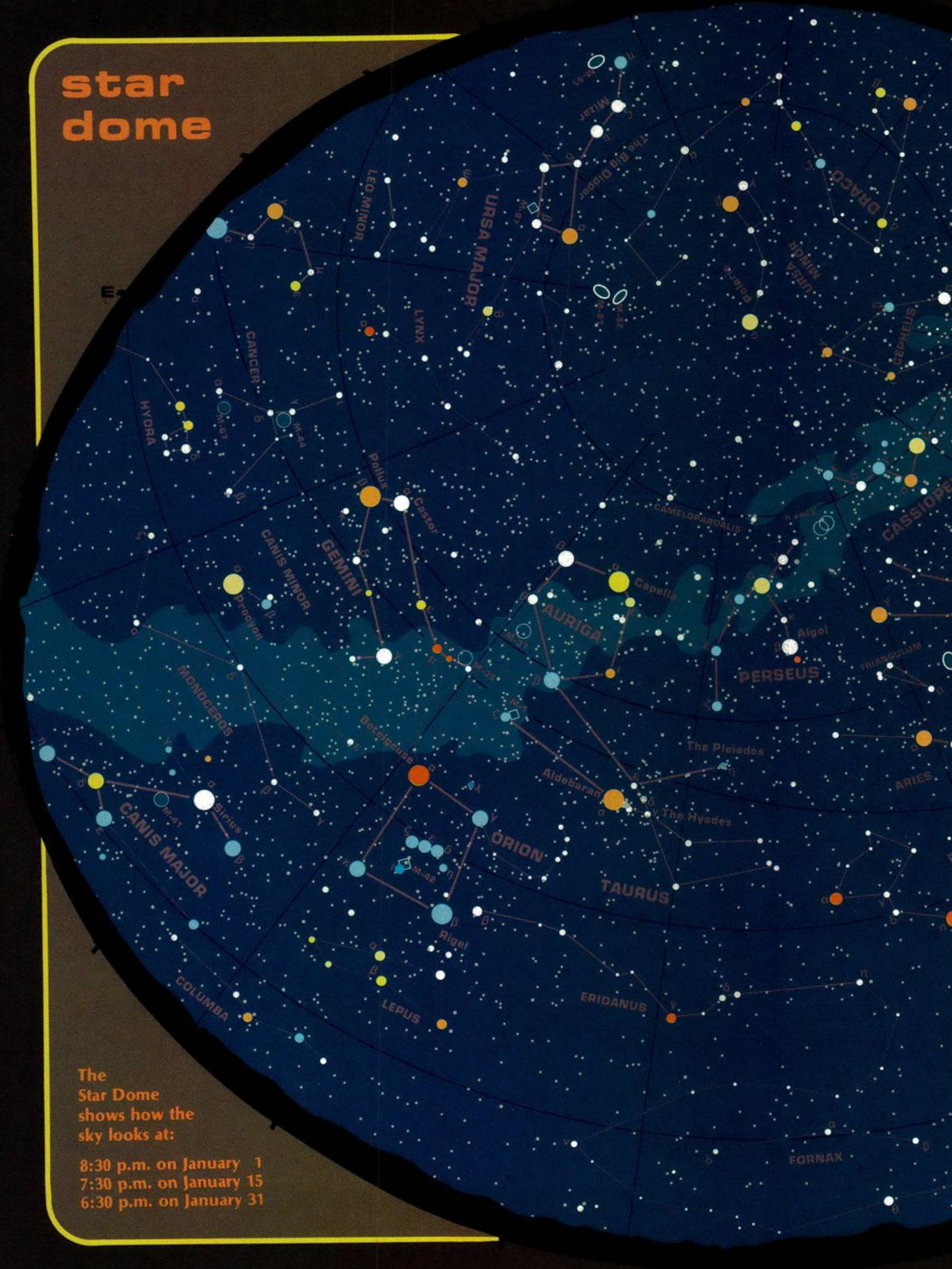
This month, some remarkable conjunctions of the outer members of the Solar System will occur. Of these, the brightest involves 6.0 magnitude **Uranus**, which will be less than a degree south of Beta^1 (β^1) Scorpii on the night of January 8. Even more impressive is Uranus' transit directly between 4th magnitude Omega^1 (ω^1) and Omega^2 (ω^2) Scorpii. Uranus is 3.5′ south of Omega^1 on January 16/17 and 7′ north of Omega^2 on the 19th.

the starry sky

Last month, we stopped at the gates of winter with **Orion** the hunter, whose belt of three stars guards the celestial equator. Above and below this belt are two first and two second magnitude stars. Let's begin our tour of the brilliant January heavens with a

High-tension power lines make an intriguing foreground for this photo of a pinpoint Venus and the Earth-lit Moon taken near Topeka, Kansas. Mike Crater captured this early evening view through a 200mm f/4 lens, with a 2½-second exposure on Ektachrome 200 as the pair descended in azure twilight.

star dome



M-51
Mizar
The Big Dipper
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M-97
DRACO
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Polaris
M-81
M-82
LYNX
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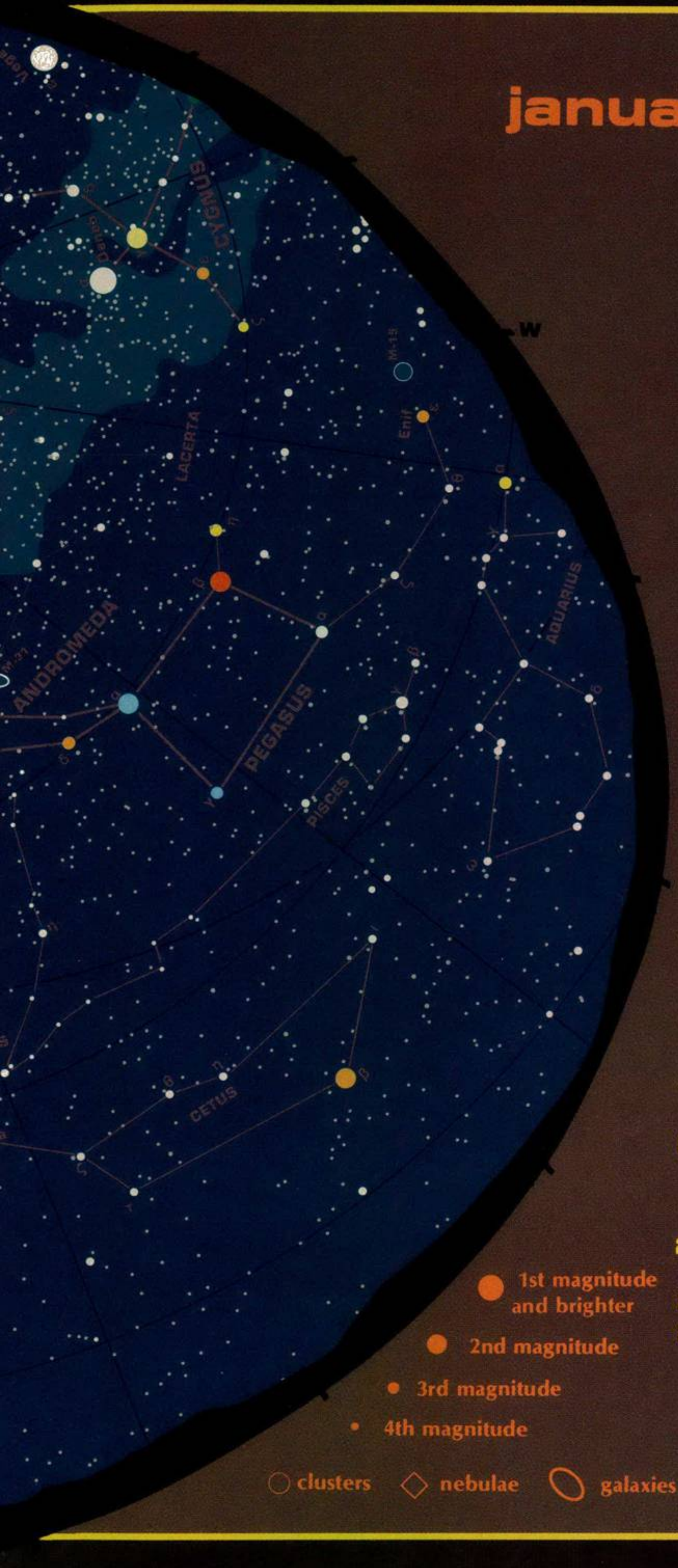
TRIANGULUM
MONOCEROS
Betelgeuse
M-1
The Pleiades
ARIES
Aldebaran
The Hyades
CANIS MAJOR
M-41
Sirius
ORION
M-42
TAURUS
Rigel
COLUMBA
LEPUS
ERIDANUS
FORNAX

The Star Dome shows how the sky looks at:

8:30 p.m. on January 1
7:30 p.m. on January 15
6:30 p.m. on January 31


Vega
CYGNUS
Deneb
W
M-15
Enif
LACERTA
ANDROMEDA
M-31
PEGASUS
AQUARIUS
PISCES
CETUS
● 1st magnitude and brighter
● 2nd magnitude
● 3rd magnitude
● 4th magnitude
○ clusters
◇ nebulae
galaxies

january sky almanac

2nd	First Quarter Moon occurs at 11:45 p.m. EST.
3rd	The Quadrantid meteor shower reaches peak activity in the predawn hours. Look for a fair number of faint, bluish meteors appearing to come from the Hercules/Draco/Bootes region.
4th	Earth is at perihelion (closest to Sun) this morning: 91,403,030 miles.
8th	Saturn passes 5° north of Spica. The Moon is at perigee (closest to Earth) this morning: 223,681 miles.
9th	Mercury passes 5° south of Venus in the evening sky, and the best time to look for it is from now until about the 20th. How much longer can you catch sight of Venus in the evening sky? Full Moon is at 2:53 p.m. EST.
12th	Mars is at aphelion (farthest from Sun).
15th	Moon passes 3° north of Mars.
16th	The Moon has passed north of Saturn and will be at Last Quarter phase at 6:58 p.m. EST. Mercury is at greatest eastern elongation — 19° east of the Sun.
17th	The Moon will lie near Jupiter in the morning sky today.
20th	The Moon is at apogee (farthest from Earth) this morning: 251,889 miles. Venus is at inferior conjunction.
22nd	Mercury is at perihelion (closest to Sun).
24th	New Moon is at 11:56 p.m. EST.
27th	Venus is at perihelion.

Mars and M-44, the Beehive Cluster in Cancer, dip low on the horizon before leaving the evening sky for another season. L.H. Price made this photo with a 135mm f/2.8 lens and a 5-minute exposure on Ektachrome 200. The Beehive now rises around 10 p.m. local time, but Mars has moved to the east.

look at this central figure.

The most interesting of Orion's bright suns is **Betelgeuse**, a red giant and the only variable star in the first magnitude class. It has a period of about six years, but often shows surprising changes in much shorter time periods. Several decades have passed since Betelgeuse has undergone one of its extraordinary brightenings or dimmings — its extreme range is 1.5 magnitudes or more. What does it look like this winter, and tonight? Check to see if it is beginning to rival what is almost always Orion's brightest star, the distinctly blue **Rigel**.

Long-exposure photographs show much of Orion shrouded in nebulosity. Its thickest region would be easily visible if it were not overwhelmed by the light of Theta (θ) Orionis. This region is the great Orion Nebula, which even a small pair of binoculars shows to be a mysterious glowing smoke-wreath surrounding Theta^1 (θ^1). The four major component stars of Theta^1 form the **Trapezium**, distinguishable in small telescopes. Theta^1 and Theta^2 (θ^2) appear as one star to the naked eye — the middle point of light in the short line of Orion's Sword. The Orion Nebula is a hotbed of starbirth that is relatively close to Earth, and therefore spectacular.

As Orion strides to his highest point in the northern sky these evenings, the constellation straight above him is pentagon-shaped **Auriga** the charioteer. Auriga is pictured holding a mother goat — the bright star **Capella** — and its three young goats — the **Kids**. The Kids shine at 3.0 (Epsilon), 3.2 (Eta) and 3.8 (Zeta), but this winter they take on a special interest because one has a mysterious nature.

Epsilon (ϵ) **Aurigae**, sometimes called Al Ma'az or Maaz ("the he-goat"), *consists of two components* — a supergiant as luminous as Rigel but twice as distant, and another object which is either the largest star identified in our region of the galaxy, a vast cloud surrounding a small star, or something even stranger. Whatever the case, we know that once every 27 years Al Ma'az slowly begins to dim and eventually fades almost an entire magnitude, down to 3.8, where it stays for about a year. This winter will be our last chance to see Epsilon at its normal magnitude, since the eclipse will begin in June and reach minimum next January.

Taurus the bull wedges its northeast pointing horns between Auriga and Orion. One horn-tip is the bright El Nath; the other is much dimmer Zeta Tauri, which lies near one of the most famous telescopic objects, the **Crab Nebula**.

According to one legend, Orion forever chases the lovely **Seven Sisters**, but they are protected from him by the bulwark of Taurus, which includes not only the bull's horns but also his orange eye, the first magnitude Aldebaran. The Seven Sisters are the bunched stars of the Pleiades, a beautiful cluster to the naked eye. North of the **Pleiades** and preceding Auriga across the sky is **Perseus**, whose head is well into the north circumpolar regions.

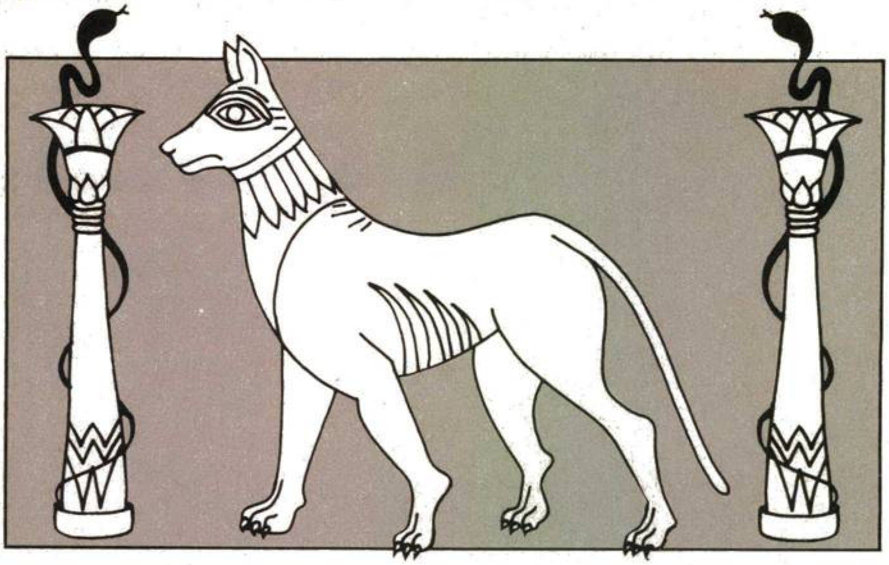
South of Orion lie the rather dim **Lepus** the hare and **Columba** the dove, but to the northeast is bright **Gemini** the twins, featuring **Castor** and **Pollux**, two stars only 4.5° apart. Gemini remains visible until late spring while the constellations which follow Orion take shorter paths across the southern sky and set much earlier.

These constellations are the hounds of hunter Orion. The lesser dog, **Canis Minor**, features **Procyon**. In any other season, Procyon would be either the brightest star or a close second, but among the winter stars it is only fourth in brightness and is more than 1.5 magnitudes fainter than the great Dog Star, **Sirius**.

skylore

Every amateur astronomer has no doubt paused on a winter night to admire the beauty of Sirius. And there is no better place to start an examination of Sirius-lore than with one of the world's oldest cultures, the Egyptian.

Sirius might justly be called the Star of Egypt, but not primarily because of its brilliance. The prominence, or dominance, of Sirius in Egyptian skylore is actually due to an interesting coincidence — the fact that in ancient times the *heliacal rising* — first pre-dawn appearance — of Sirius closely coincided with the life-giving annual flooding of the Nile.



This flood, which sustained the crops and the people of the desert land, is not dependent on Sirius, of course, but rather on the rainy season farther up the Nile which guarantees that rising waters will reach Egypt around the summer solstice. Precession has moved the solstice point west so the heliacal rising of Sirius now occurs long after the solstice — in early August for Egypt. However, in 3285 B.C. it took place right at the summer solstice and therefore the return of Sirius was a harbinger of the Nile floodwaters.

The Egyptian New Year coincided with the coming of the flood or rather with the heliacal rising of Sirius, which was its precise indicator. The Egyptians counted the days from one heliacal rising of Sirius to the next and determined the length of the year to be 365 days. In the following centuries observers noticed that the calendar date was falling behind astronomical and other natural events, and calculated that in 1,460 years the date would regress all the way through the year back to its original position in relation to the natural world. The 1,460 year period became known as the Sothic Cycle, after *Sothis*, the Greek translation of an Egyptian name for Sirius, *Sopdet*.

But Sopdet was not the only title given to Sirius in the long history of ancient Egypt. In fact, the star was associated with many deities. The hieroglyph of the star is said to be a dog, but on the famous Denderah zodiac, it is represented by a cow in a boat with a star above its head. The star also appears as the goddess Satet accompanied by Anukt with two urns pouring out a symbolic flood of the Nile.

Satet and Anukt were wives of Khnemu, a river god once worshipped as creator in parts of Egypt. But Satet and Sopdet were also goddesses who became identified with Isis. The star Sirius was long regarded as the resting place of the soul of Isis. Later the star was even identified with Osiris, the husband of Isis, whose name may be related to the name Sirius.

Yet another goddess with whom Sirius and Isis were identified was Hathor. The Jobeses relate a tale that Hathor eventually "multiplied into seven Hathors — the seven bright stars of Ursa Major." These Hathors are described in a work on mythology as "kinds of fairy godmothers who sometimes appeared at the birth of a young Egyptian to prophecy his destiny."

Sirius was also connected with the god Thoth who was represented by the ibis and considered the creator of all the arts and sciences. The star may also have been seen as Anubis, the god with a jackal or dog head, who invented mummification and weighed the souls of the newly dead against a feather to determine their guilt or innocence.

So in the thousands of years of ancient Egypt, a large land whose different regions sometimes worshipped different gods, Sirius was connected with many of the chief deities. Study of even the basics of Egyptian Sirius-lore can serve as an introduction to Egyptian mythology. In Egypt, Sirius was also known as the Starry dog; as Sihor, The Nile Star, and as the Fair Star of the Waters.

But what is the source of the name Sirius itself? It may stem from sources more ancient than the Greek, but it is probably derived directly from that language. *Seirios*, an adjective originally applied to any bright or sparkling object in the heavens, is a Greek word. But which is it — bright or sparkling? Or is the best translation, as many have it, "scorching," which presumably refers to the myth of Sirius-heat in the dog days. The adjective was also applied to twinkling stars, and the twinkling or sparkling of Sirius is easy to notice. The Sun was described with this adjective, too, and the Sun does not twinkle, so the definition probably refers to the brightness or the scorching. The origins of this very old name still remain a mystery.

ASTRONOMY
IN FOCUS

Her Future in Space

Sir / I'd like to express my views on a heart-sickening matter — the cuts in space exploration funds. It upsets me to see the government playing politics with it. When something exciting is happening, they applaud NASA and give the space program praise. But when it comes time to dig into their pockets, they decide it isn't so great. I hope that they come to their senses and realize how important our space program really is before it's too late. I am 15. The space program is to become my future — if it's still there.

Lissa Hill
Walnut, CA

Concerned Citizen for Space

Sir / I have become increasingly concerned about the negative approach the Administration and Congress have taken toward space program funding. Ironically, public support for space is at an all-time high. As concerned citizens, it is our duty to inform the politicians of our opinions.

With this in mind, I sent 26 letters expressing my support for the space program to various elected representatives, including most of those listed in the May 1981 issue of ASTRONOMY. I have received eight replies so far, all expressing some degree of support. A majority of those who responded mentioned current budgetary constraints, and the possibility for increased support after we have surmounted our country's economic weaknesses.

Unfortunately, opportunities such as the return of Halley's Comet do not wait for improved economic conditions. And if we devastate current programs we might never recover our lost lead in space exploration. I urge everyone to show support by writing at least four letters: one to each of your two U.S. Senators, one to your Representative, and one to the President. If we continue to speak, we will be heard.

Stan Shull
Troy, NY

On the Value of Voyager

Sir / The Voyager program's two spacecraft have dramatically increased mankind's knowledge. We will still be thinking about these planetary flybys for years to come. However, there is another valuable role Voyager plays: as a symbol of the human race.

A few nights ago, as I was observing a star in Pegasus, I realized how insignificant Earth really is. Long after any trace of the human race has been erased from the Earth's surface, Voyager will be out there among the stars, a record of who we once were.

Juris Breikss
Littleton, CO

Serious Cuts

Sir / Cutting NASA's budget will be a great loss. It is especially sad to see the mission to Halley's Comet given up.

I have read that the Europeans, the Soviets, and the Japanese are sending out probes. Maybe if we Americans don't have enough money to send a probe to Halley, we should swallow our national pride and join in their efforts. Wouldn't it be better than doing nothing at all? If we all worked together, we could promote peace in the world instead of hatred.

Tom Filarecki
Omaha, NB

Gung-ho for Space

Sir / It appears to be fashionable these days to criticize the military's role in the exploration of a new frontier. Yet in all the furor, everyone seems to have forgotten that without military support there would be no Space Shuttle. And therefore there would be no Space Telescope, no solar sailing, no space colonies.

We often overlook the fact that it was the Soviets who first "militarized" space in a big way. The United States is trailing behind: the Soviets have an operational antisatellite weapon system now, while the U. S. won't test one until next year — and it will not be operational for some years after that.

Historically, the military has always been first to move into any new frontier. Of all the organizations in a culture, the military is the most likely to have the funding, the resources, the technical capability, and the will. I see no reason to expect things to be different in space.

Indeed, NASA is extremely unusual. Very few cultures, if any, have ever supported such an extensive research and development organization of little immediate practical benefit. But even Apollo was indirectly military, and the Voyagers were launched on military rockets — the Titan III-E Centaur — developed from the Titan ICBM.

It would be nice to have an entirely civilian space program, and I would be the first to support any politician who proposes such an endeavor. But Man is an aggressive animal. I think it unrealistic, to say the least, to require that some ten million years of human nature be reversed before we can move into space. After all, it is this very aggressiveness that drives us to explore. We should recognize this and get the military to use some of its large-scale engineering capability for something other than killing *people*.

Laser or particle beam battle stations in space could be one of the best things that could happen — for the United States and for the world as a whole. As well as making possible a true defense against a nuclear war that seems ever more inevitable, such weapons will require the building of a vast fleet of shuttles, logistical space stations, and construction facilities in orbit.

I suspect that, realistically, this is the only way to convince Congress and the Reagan Administration to build such expensive equipment. Then, after we build our battle stations in space and strategic warfare is once again temporarily impossible, the facilities can be used as bases for orbiting observatories and jumping-off points for other explorations we'd like to see — including, perhaps, manned missions to the planets. This scenario has been very common throughout history and, again, I see no reason to expect things to be different this time.

And best of all, such a massive move into space could buy us time to start thinking about ways to eliminate our preoccupation with warfare, without eliminating the urge to explore.

Donald F. Robertson
Sacramento, CA

In Too Deep

Sir / I have been bitten by the astronomy bug and have overloaded myself with a growing list of expensive accessories for my 6-inch reflector. I own tube counterweights, a guidescope, a battery pack, drive corrector, etc., etc. You name it, I got one.

But it takes forever to set it all up, and now I'm wondering if it's all worth it. I can't mount the scope permanently because there are too many trees in my yard, and the long drive to the club observatory is getting too expensive, what with gas and all.

Sometimes I forget a simple tool and ruin the whole night. It's really frustrating. This all costs me time as well as money and I'm trying to find ways to cut back. If I can't, I may be forced to get rid of it all. What can I do?

Stephen Stoffer
Grand Rapids, MI

Dear Mr. Stoffer / We have long recommended that our readers not plunge into any hobby activity too quickly. However, since you already have the equipment, we recommend you give yourself a cooling-off period.

For the next six months, forget the accessories. Go out with the telescope for a while and observe again with clear eyes and an open mind. Let the frustrations fade away. When the time comes, gradually get back into photography step by step. Let yourself build the skills and expertise slowly — then you'll find you're enjoying yourself.

Uncluttered Observing

Sir / This letter is not meant to stick it to the big-money amateurs, but hopefully it will encourage the low-budget observers to come out of eclipse. Those of us with 3-inch reflectors or binoculars can still see a lot. No, we don't have all the motor drives and equatorial mounts and research eyepieces, but we're happy anyway.

We're happy with the same binoculars we use at the Philadelphia Eagles games, or with a friendly little homebuilt telescope. Our desks aren't cluttered with calculators and gadgetry, but you'll find a star chart and our notes from last night's observations. We may not see the dust lanes in the Andromeda Galaxy, and something like the Trapezium in M-42 is right at the limit, but the Moon comes in bright and beautiful.

We enjoy watching the meteor showers in August and picking out the planets and stars all year long. We enjoy ASTRONOMY magazine, especially Eye on the Sky, In Focus, and The Backyard Astronomer. We tend to skip the Technical Stuff. Yep, our little apartment of space is roomy enough to provide all the pleasures of space — and the rent is very low.

Paul King
Toms River, NJ

Ooops!

In our story on the Magellanic Clouds (October 1981), the last two sentences of the fourth paragraph in the second column on page 16 should read: "To judge by the Clouds' velocities with respect to the Sun, such a separation would take about 300 million years. Interestingly, this is about the time that has elapsed since the clouds last passed through the outer parts of the Milky Way — if they are, in fact, satellites orbiting our Galaxy."

behind the scenes

how you can help

If the ailing space program ever needed our support, it needs it now. Faced with additional budget cuts of $367 million from the Fiscal Year 1982 budget, and further cuts estimated at $1 billion from both FY83 and FY84 budgets, NASA is considering major cuts in planetary exploration. The American mission to Comet Halley was dropped even before this round of budget slashing. Now we must fight to continue the successful Voyager mission on to Uranus and Neptune, to keep the Deep Space Network in operation, to prevent cancellation of the Galileo mission to Jupiter.

What can you do? Write to your representatives in Washington. Let them know, in a concise one-page letter typed and double-spaced on 8½" x 11" paper, that you support NASA's planetary exploration in particular, and NASA in general. Mention the benefits that we receive from space exploration — increased national prestige, the technological growth that comes from space missions, the role space plays in encouraging young people toward high-level careers, and your pride that America leads the world in this endeavor. Be specific — mention Voyager, Galileo and VOIR.

Avoid negative comments about other federal programs. Avoid slogans, emotional outbursts, vote threats. Be positive.

Write to both of your U.S. Senators (use the salutation Dear Senator Smith; for the address: Hon. John Smith, U.S. Senate, Washington, DC 20510) and your U.S. Representative (use Dear Mr. Smith as the salutation; and for the address: Hon. John Smith, U.S. House of Representatives, Washington, DC 20515). Don't delay — and keep writing letters. It also wouldn't hurt to let President Reagan know that you support space exploration.

Sincerely,

Richard Berry

Richard Berry
Editor

(ADVERTISEMENT) (ADVERTISEMENT)

NUMBER ONE IN A SERIES OF TECHNICAL COMMUNICATIONS (OPTICS, PART 1)

1

WHY CELESTRON® OPTICAL QUALITY IS UNBEATABLE

This is the first of a series of bulletins which will explain the design philosophy and some of the technology that has propelled Celestron International from a specialized manufacturer of large custom telescopes and research optics to the world's largest manufacturer of select modern telescopes. Why do we present this material? Celestron International remains committed to providing you, the consumer, with not only the best telescope value available, but also to provide you with the world's best customer service. Celestron has organized the world's largest network of telescope dealers to assist you in the use and selection of telescopes, with the ultimate goal of securing only satisfied customers. We encourage you to contact a Celestron dealer for information and a demonstration so that you can see for yourself the quality and versatility of the famous Celestron telescope—the best telescope value today.

PROVEN AND ACCEPTED QUALITY

That Celestron's Schmidt-Cassegrain optical design is the best optical system for general amateur astronomy is practically unquestioned: *tens of thousands* have been delivered to individual amateurs, specified by astronomy clubs, ordered by schools and utilized in university research and industry. It is the best selling modern telescope in the world. The Celestron Schmidt-Cassegrain system must be good; it has been imitated by competitors and it is the standard against which all newcomers attempt to compare themselves. Celestron would like you to know that, among all telescopes offered to you today, Celestron still manufactures the best Schmidt-Cassegrain telescopes and that Celestron optics are still, by far, the best in terms of being better corrected for aberrations (overall optical quality) in the manufacturing process. We could say repeatedly that we're the best, and we could take you to our testing devices and show you the difference, but that may not be understandable or convenient to the average telescope buyer (how easily could you trot down to Torrance to see our demonstrations and products?). But the real evaluation of Celestron quality comes from a third party—our past or current customers. Ask our telescope owners, ask educators and planetarium staff and ask telescope/camera dealers—they'll tell you that Celestron stands alone as the best quality and best value in telescopes on the market!

Celestron 8 Telescope

OPTICAL QUALITY OF THE CELESTRON

A question that any optical manufacturer must ask is: What is good optical quality and how do I assure that I'm producing a good product? The standard of optical quality long recognized by the amateur astronomical community is the "Rayleigh Criterion" which states that if the optics of a telescope have errors (physical departures in the shape of the optical surfaces) that yields a wavefront (the wave-like condensing of the light to form an image) of less than or equal to ¼-wavelength different from that produced by a *theoretically* absolutely perfect objective, *then* the image that will be produced will be essentially perfect. Hence, when your telescope has ¼-wave optics, you should have usable optics whereas better optics have physically measurable errors smaller than ¼-wave; such as ⅙ or ⅛-wave. Celestron International warrants its optics to be ⅒ wave——optical quality far above what is necessary for enjoying your telescope.

HAND FIGURING

Celestron goes beyond simple manufacturing practices and *assures* optimum uniformity and performance by the labor-intensive task of hand-figuring each optical system in its astronomical telescopes. Celestron, and Celestron alone, to the best of our knowledge, is the only Schmidt-Cassegrain manufacturer that always hand-figures each optical system it makes. Other manufacturers, to the best of our knowledge, use methods that introduce substantial variation into the figure (the optical shape). What is hand-figuring? This "matching" procedure employs a highly skilled optician to place optics on a double-pass autocollimator (a test device) and utilizes four tests: inspect the Airy disk, test for spherical aberration by inspection of the out of focus diffraction images, the Ronchi test, and a null or knife-edge test. Based on the interpretation of these tests, the optician custom manufactures a pitch lap for one of the elements of the particular optical system under examination and gently hand polishes any irregularities out of the system. This process is repeated until a smooth optical figure free of localized optical errors (zones) is produced. You are invited to see our quality control station should you ever visit our Torrance, California factory. We think you'll find that no other manufacturer is so open in explaining and demonstrating its products or so proud of its accomplishments. Celestron's matching process produces a telescope that has optics that are not only of ⅒-wave, but also of exceptional *smoothness* such that an overall averaged departure of the optical accuracy is 1/30-wavelength expressed as the root mean square. This difference can be seen in optical tests as well as in actual use of the system. What does this mean to you, as an observer or photographer? Simply, higher contrast images. The smoother the optical figure, the *fewer* small abrupt surface changes there are on the optical surfaces, the better defined the images the telescope can deliver (technically less light is diverted outside the diffraction disk).

COMPARE CONTRAST IN IMAGES

The Celestron 8 will demonstrate nicely its high optical quality when you conduct a side-by-side inspection with competitive Schmidt-Cassegrain telescopes. When you inspect a stellar image, you'd find the Celestron's would be closer to the theoretical "diffraction image" a very small round ball (the "Airy side") with a single ring around it. The images in competitive scopes would show more scattered light (the Celestron will always concentrate a greater percentage of starlight into the primary maximum or Airy disk)—the stars would not be sharp points, closer binary stars would not be as cleanly separated and details would not be as cleanly separated and details would not be as visible on low contrast objects such as the delicate festoons in Jupiter's atmosphere or the swirls of nebulosity in the Orion Nebula (M42). The optics of the other telescopes may also show such optical irregularities as astigmatism, down or upturned edge, undercorrection or overcorrection, all of which are eliminated with Celestron's unique matching.

Not only would you see a difference between a Celestron and a competitor's telescope, but you would also, upon inspection of many instruments, see the uniformly good results from Celestron. Because of our matching techniques, every telescope is of high optical quality—with competitive brands good optical performance is likely to be a hit-or-miss proposition, some will be good and some will be mediocre. Which do you wish to use?

Celestron®

Celestron International, 2835 Columbia St., Box 3578-B, Torrance, CA 90503 (213) 328-9560

bradfield's dozen: a guide to comet seeking

by Ben Mayer

"876 Lower North East Road, Dernancourt, Adelaide - South Australia, it's all very easy to find." The letter had been explicit: "My home is about a mile past the shopping center. It's next to the first big old pine tree you see adjacent to the right hand edge of the road. The number is plainly visible on a large brown letter-box. The house — a flat roof structure — is set lower than the roadway and is partially hidden . . . "

For William A. Bradfield, discoverer of eleven comets (as of the end of 1981), such earthly things must be easy to find indeed. More difficult is the search for comets.

He was waiting for me by the side of the road, in the shade of the big old pine: "I saw your plane going over, so I thought you'd be arriving about now," he said as we shook hands. I had come halfway around the world to make his acquaintance and to pay homage.

The name Bradfield has been spoken countless times by astronomers, both amateur and professional, since he found his first comet early in 1972 from the backyard of the house which I was about to enter. Tall, ruggedly handsome, eminently self-assured, he clearly does not seek the hero worship which his name can readily evoke among stargazers.

A methodical man, he was completely prepared for this visit. He had taken the day off from his work at the Department of Defence's Weapons Systems Research Laboratory, where he is research scientist in charge of the rocket propulsion research group. He seemed ready and willing to share his experiences and to talk about his methods and techniques for finding elusive celestial visitors. He spoke in a soft voice, but with the pronounced "down-under" accent of one who had been born and lived in New Zealand for half his life and had spent the other 25 years or so in Australia.

Even though he had become interested in astronomy at an early age, and had started observing "with a very small telescope" while living on a farm at about age fifteen, his interest in comets was not aroused until early in 1970. Comet Bennett was a then spectacular object in the morning sky. "That fired me," he muses. Later that year he bought a comet-hunting telescope from Ralph Sangster, a friend and fellow amateur who had built it.

He describes the instrument: A refractor with a six-inch objective — an old type portrait lens which may have been made at the turn of the century or perhaps even before. Its focal length is 33 inches, f/5.5 and, fitted with a wide-angle eyepiece, it yields a magnification of 26 times. The field of view is approximately 2¼ degrees.

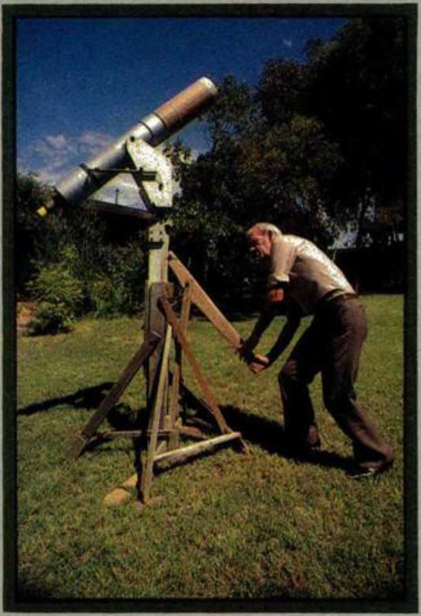
"Do you want to see the telescope?" he asks almost as a formality, because he must know that you do. It is evident,

Comet Bradfield (1980t) reached naked-eye brightness and put on a brief but impressive show during the last days of 1980. Photograph by Daniel Gray.

though, that he is just as eager to show his prize. You leave the shelter of the cool and modern interior of the living room and step into the garden where the late summer sun blazes almost directly overhead. The azure blue sky is festooned with wispy clouds. It is February. The latitude is 35 degrees south.

Nothing prepares you for what you are about to see: First, the fourlegged telescope support. Three legs are fixed, one is hinged to act as an adjustable buttress on uneven ground. The structure is a conglomeration of assorted two-by-fours with holes drilled in them. A protruding lever jutting out from the central vertical stand suggests the tiller on a decrepit barge. It is a nuts and bolts assembly. You have seen better constructed saw-horses. Raw lumber all; if the wood has ever seen paint, it has long since disappeared.

Bradfield setting up his comet-seeking refractor. Photo by Ben Mayer.



Now comes the telescope itself: vaunted instrument, wellspring of eleven solo discoveries, envy of comet hunters around an entire planet — a glorified stovepipe. He carries it from his car with barely concealed pride, makes a little lateral detour to show the refractor broadside, and, when he notices your camera clicking, cradles it lovingly in the alt-azimuth mount. His motions are easy and quick, bred from countless assemblings in dew-damp, pre-dawn darknesses.

He demonstrates the "tiller" — and it proves to be an efficient device, allowing him to raise or lower the telescope to the level for easiest viewing at any altitude. Even though Bradfield prefers to observe in a standing position, he regards comfort as paramount. There must be no strain he insists.

With a thin skewer-shaped pin he secures the sliding vertical post at a height convenient for a demonstration. He shows the telescope components: the heavy 1¼-inch Erfle eyepiece sliding in a massive 3-inch barrel which is, in turn, soldered to the end plate on the 6-inch tube. He removes a plain corrugated cardboard dewguard to reveal the old Dallmeyer Petzval objective lens. It is held in a brass cell which is covered from end to end with tightly wound garden-variety twine.

"The winding increases the outer diameter so that the cardboard dewcap will slip on firmly without fouling the protruding ring on the forward end of the cylinder," Bradfield explains.

Unasked, he demonstrates his basic sweeping procedure. First, he adjusts the elevation angle with a knurled knob working a rack and pinion assembly on the right side of the scope. Then, to block out all stray light from the vicinity of the ocular, he shelters his face within a smallish cardboard box with a hole in it for the eyepiece. There is a crescent-shaped cutout to accommodate his forehead. "40 Koolpops" advertises the kraft-colored container. Australian popsicles?

His right hand rests on the eyepiece as he slowly pushes the telescope in azimuth along the sweep path. He shows his "charts": Half-size photocopies of pages from the *Atlas of the Heavens.* On these cardboard mounted maps, diffuse objects — even faint globular clusters which might be mistaken for comets by beginning seekers — are bracketed for easier identification. Most of them have long since become familiar to the experienced Bradfield.

When he refers to his maps he uses a small penlight wound with red tissue paper and secured to his neck by a loop of string. It is an understatement — no rechargeable, dual-color always-ready flashlights for this observer.

The telescope knocks down for transportation to preferred viewing locations. Over the years, Bradfield has observed from about sixty sites, but most have been abandoned as he gradually moved farther from Adelaide to find dark skies and better viewing conditions. He pinpoints his "evening sites" north of Adelaide on the map. For the morning, he prefers the higher ground northeast of his home. When low clouds or fog roll in, he moves from these ranges to lower ground.

In the garage he shows a new comet-spotting telescope nearing completion. Designed with all of his requirements in mind, it is a marvel of ingenuity and compromise. Somehow, though, you feel that the trusted Sangster/Petzval scope will always remain his preferred instrument.

The optical criteria for comet spotting systems confront the comet hunter with a trade-off, Bradfield explains. Large aperture — which permits the detection of faint comets — can only be used at the expense of smaller fields of view, thus requiring a greater investment in time spent sweeping a certain region. As a rule of thumb, the lowest magnification should be used. Since most dark-adapted pupils are 6mm or more in diameter, for telescopes with objectives of 120mm or more, you must divide the aperture in millimeters by six. In instruments with apertures smaller than 120mm, magnification should be no less than 20 times; this permits the observer to distinguish small star-clusters which might otherwise appear as diffuse objects. Successful comet hunters prefer apertures in the 150mm range with a magnification of 25 and a clear field of two degrees.

The telescope mounting must permit continual sweeping, often two hours or more at a time. Alt-azimuth configurations are best since long lateral sweeps at low elevations are required. For catadioptric telescopes, this simply means that comet searching is best done without the equatorial wedge. For larger refractors, any system which keeps eyepiece movement to a minimum — particularly vertical movement — is helpful. The newest Bradfield design for a reflector telescope places the eyepiece near the axis of rotation of the telescope.

As if to stress the value of the alt-azimuth mount and the productivity of searching low and near the horizon, Bradfield gives the substantiating data. Of 436 new comets discovered visually from 1750 to 1967, nearly half were found at elongations between 30° and 70° from the Sun. That is why it is best to search in the evenings, after astronomical twilight when the Sun is 18° below the horizon or, better yet, in the morning sky before it begins.

Such comet information pours forth with ease. Bradfield is a fountain of knowledge in an area that has become rightfully his. Only Leslie Peltier (1900-1980, American) and Minoru Honda (born 1913, Japanese) have, in recent times, exceeded Bradfield's score. For the Australian, the game is far from over. He speaks of Peltier with admiration and respect, as of a mentor, and frequently quotes him: "If you want to find comets, keep looking."

I look at the cloud-filled sky. "The

William Bradfield discovered 1980t on December 17 as it brightened and moved rapidly toward the Sun. Photograph by Richard Sturdivant.

weather is always critical" he states as we return to the house. He makes a special point of stressing the importance of maintaining the search program consistently, year-round, despite the cold of winter nights. Then he tells how he dispels the frustration of reduced observing time during cloudy weather by making the best use of every clear night.

The small tape recorder which, until now, you have kept under wraps, suddenly seems invaluable because you want to capture not only his words, but the way he expresses himself, literally, word for word. He does not object to talking into the microphone:

Q: Please tell us your comet story from the beginning.

A: After I bought the telescope from Sangster, I decided I would take up the task of looking for comets on the first of January 1971.

Q: Where did you look first? Had you read anything on the subject or did you just go out and start sweeping?

A: At first I spent some time observing the comets which were visible at the time, for example Comet Abe, to get a feel for what comets looked like through the telescope. Then on January first I set out to find a comet. I simply divided time for searching both the morning and the evening skies. It was not a matter of reading about other people's experiences — there was very little material available — it was a matter of finding out as I went along.

Q. Where exactly did you look? Was the "haystack theory" familiar to you?

A: Well I must admit that I had known for a long time that there was a greater chance of finding a comet in the vicinity of the Sun, so I did spend more time looking in the west after sunset and in the east in the morning before sunrise. But I also spent a lot of time looking farther afield, going as far out as perhaps 120 degrees elongation from the Sun. I have since realized that the most profitable areas are near the Sun. In fact, various analyses of past comet observations suggest that one might — with a good coverage of perhaps between 30° and, say, 70° elongation from the Sun — expect to find something.

Q. How long was it from the first day you started looking, until you actually found your first comet?

A. In 1971 I ran up 180 hours without success. It was not until the early part of 1972, after having spent another 80 hours, that I was lucky enough to find a comet in the morning sky from my own backyard.

Q: Did you work equal numbers of hours in the morning as in the evening, or did you favor one over the other?

A: At the time I would have been spending perhaps the same amount of time in the evening and in the morning. There is a greater chance of discovering a comet in the morning sky, so it was my intent to spend more time in the morning. But what really controls searching time is the weather. Sometimes you might hope to do more in the morning, but you just can't do it because of cloudy skies.

Q: How is the weather in these parts, Adelaide in particular?

A: The weather is fairly good. I must admit there would be more chance of finding a comet in South Australia than, say, in New Zealand, where, of course, there is greater rainfall. Rain in Adelaide comes to about 20 inches a year, and during the winter months the hills are quite cloudy. But during summer one can expect clearer skies. If one is prepared to get out whenever the sky is clear, there is no trouble in running up appropriate search hours.

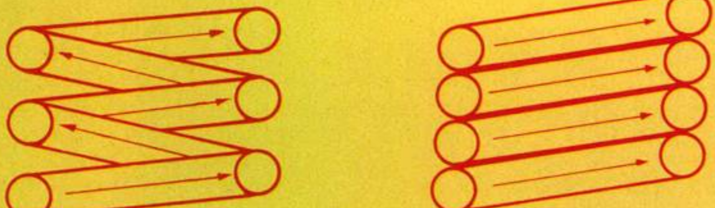
Q: Did you, right from the start, devote maximum time to your search?

A: The effort in the initial days was really to cover a given area of sky over a set period of time. The Moon was the controlling factor. Once you have covered a certain part of the sky while there is no Moon, there is not much point in doing another search until another two weeks have gone by. So it was not a matter of working at it and working at it: it was a matter of just covering the available sky and then resting and waiting for time and then doing it again.

Q: With the 2¼° field of your telescope, how much overlap do you have as you sweep and patrol?

A: As little as possible. It depends how you operate the telescope, and

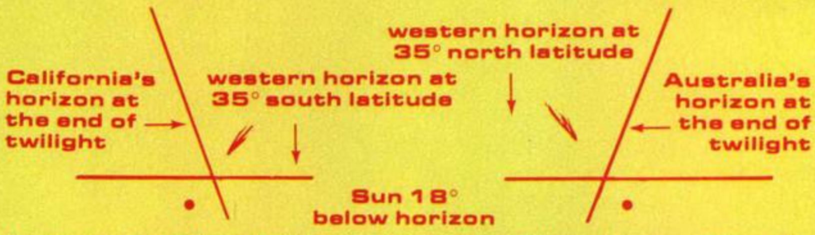
efficient sweeping for comets



the zig-zag pattern leaves unsearched gaps

the one-directional pattern covers the sky

searching the twilight sky


California's horizon at the end of twilight
western horizon at 35° south latitude
western horizon at 35° north latitude
Australia's horizon at the end of twilight
Sun 18° below horizon

Northern and southern hemisphere observers see different regions of the sky near the Sun. Both might catch the same comet, but large areas of sky do not overlap. Diagram by William Bradfield.

on which way the skies are moving, whether rising or sinking. It's through experience that you get to know how much you should overlap. I find it's preferable to overlap more, rather than to miss out any areas. It would be embarrassing, I feel, at least from my point of view, to find that I had missed an area, and to find afterwards that there was a comet in it.

Q: The Moon pretty much governs when you observe. Could you expand on this?

A: For evening observations I wait until the Moon gets beyond full, perhaps three days after Full Moon, or maybe four. Then I can get out in the evening sky and get some dark-sky viewing, perhaps half an hour or an hour before the Moon comes up over the eastern horizon. I try to get most of my observing done then, weather permitting. I might even spend two or three days searching the dark sky, covering areas I want to cover before giving the game away, as it were. Because by then I would conclude that there was no comet there.

I would then wait, and perhaps a week later, maybe less than that, as the Moon would be getting toward new, certainly three or four days before New Moon, I would get up in the early hours of the morning to cover some of the eastern sky, low in the east, before the Moon comes up. If the Moon were still bright, I might give up when it rose.

When the Moon gets to about three days before new, and is not bright anymore, I will cover all the available sky, right down to the horizon, working right up to the time of twilight. In the morning I will get out perhaps two hours before twilight and set up the telescope. I point it at an elevation of 20 degrees. Then I horizontally scan the sky, working gradually upward to an elevation of 50° or maybe 60°. That might take me an hour or so.

In the meantime, the whole area which I had covered would have moved higher in the sky thereby offering me another slice of sky which had risen up from below. I would then drop the telescope back to a 15° elevation and work up again covering the new small slice of sky which had just risen. By that time it would be getting near twilight, so I would drop the telescope once more, right down to the horizon, and scan the remaining 15 or 20 degrees. I might spend just 15 minutes on these low elevation areas.

Recently, however, I have continued as long as 20 minutes into twilight and was able suddenly to come across a new comet which was very low in the sky. This has happened twice recently. By working in the twilight I was able to cover some remaining ground and was fortunate to come across a bright comet.

Q: You drive considerable distances, both morning and night, to your observing sites. You knock down your telescope, put it in the car, and then set up again. How far do you drive to your observing sites?

A: In the evening I travel north 35 or even 40 miles, taking about an hour to get to the site. I set up in a matter of two or three minutes and will then spend an hour or two at the site. Then I motor home again for another hour. In the morning I get up early enough to allow for the traveling time. When twilight sets in, I'll pack and return home which takes another hour.

Q: When you speak of hours spent comet hunting, does that include driving and set up?

A: When I speak of hours, I mean actual observing time, with the eye on the eyepiece and with the telescope being moved to scan the sky. This time also includes the time it takes for me to decide what is there. In other words, if I have to refer to a chart for an odd minute or so, then that time is also included. As the time goes on, however, I find I am becoming more knowledgeable and I refer to the charts less and less. Today most of the time spent is actual observing time at the eyepiece.

Q: Could you give some breakdown on the time that you have so far spent for your eleven discoveries and your average search time per discovery?

A: In making eleven discoveries I have spent close to 1600 hours. So the average time is round about 160 hours per comet or per year. It happens that I have spent about ten or eleven years doing this.

Q: Your time for observing and driving adds up to about four hours per morning or evening session. How many times will you do that in a month?

A: The Moon goes through its phases once a month: I expect to cover the evening sky at least twice in that period; that means the beginning of the Moon-free period and then the end of it. Likewise I expect to do the same in the morning. That would make at least four excursions — even as many as eight — during one month to cover all the areas of sky which I want to survey.

Q: And you do this all year?

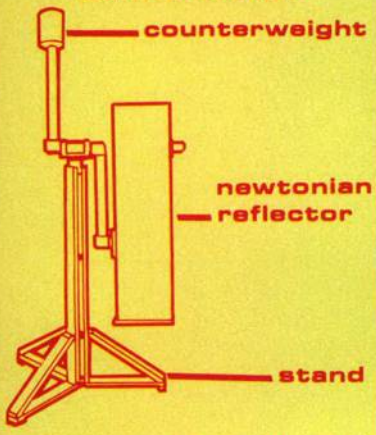
A: Yes, every month. Of course in wintertime it might be more difficult to find days which are clear. You may not be able to go out on your preferred days and you may have to wait until clear skies allow you to go.

Q: Do you communicate with other comet-searchers?

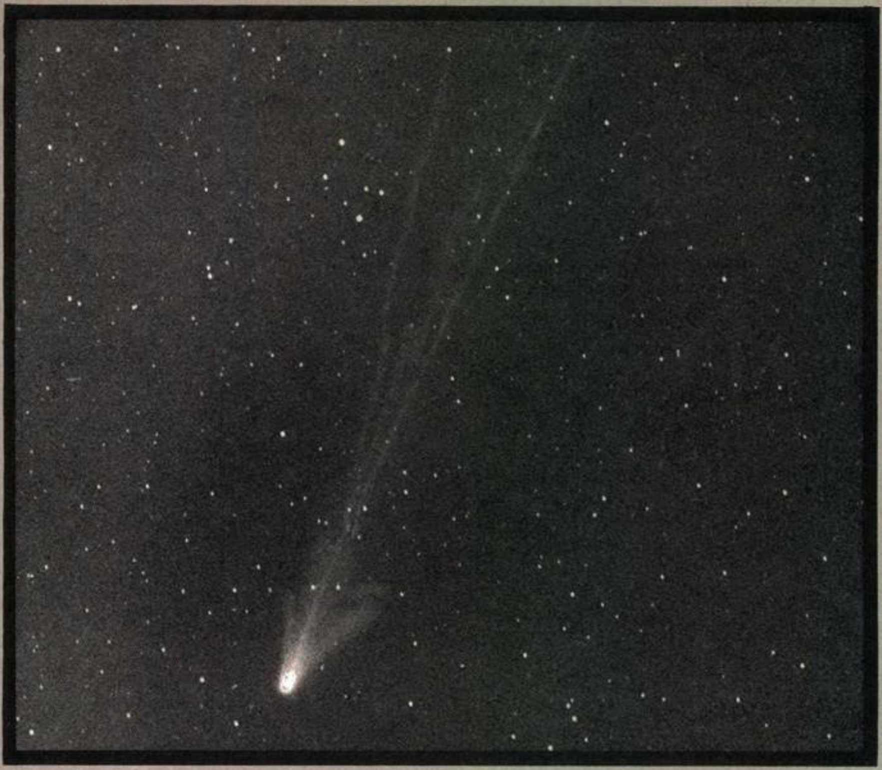
A: Over the years I have maintained quite a correspondence with other comet-hunters, or even comet observers, who like to hear what I have been doing or who write to congratulate me and so on. There is a large number of people who hunt comets. I like to share their experiences and perhaps learn something from them.

Q: I remember hearing Don Machholz of Los Gatos, California, say that he does not search the area of the

a reflecting comet seeker



This simple alt-azimuth pipe-mounting keeps the eyepiece at a constant height for sweeping while standing up. Drawing by William Bradfield.



Comet Bradfield (1979l) displayed two distinct tail structures — a long thin gas tail and a broad short dust tail. Photograph by Greg Griffith.

Virgo cluster. Do you?

A: No, I don't. There are also some other areas which I keep clear of. One is the Large Magellanic Cloud, which contains many comet-like objects. I would never choose to spend much time on that.

Q: It is often said that you have the entire southern hemisphere sky all to yourself. Surely there must be others?

A: Of course there are. They are in South Africa, in Australia, in New Zealand. I don't know about South America; there could be some there as well. I must say, though, that the total number would be far less than could be mustered in the United States, Europe, or Japan.

Q: The Japanese may well be the most avid sky-watchers of all. Could you estimate how many people are searching there?

A: Well, I don't really know the exact number, but I wouldn't be surprised if there were at least fifty persons in Japan doing a very regular search of the sky simply to find comets.

Q: How many would you think are there in the U.S.?

A: That's a very difficult question. Several dozen — but I might be low.

Q: Do you remember your first discovery? What happened?

A: My first discovery was from my backyard, after running up a total of 260 hours. I must admit it was a big surprise suddenly to realize that there was a comet in the field after working for so long. I was very excited and I described the object to my family as a "bug" (laughs) that had appeared from nowhere. It was about magnitude 9 or 10 and it appeared as a normal comet — just a diffuse looking object.

Q: Were you ready to report it, did you have all your data together, this being your first comet?

A: I was able to send a telegram to Dr. Marsden in the United States. I was aware of the existence of a special code and knew how to code the message. Unfortunately the first telegram did not reach the bureau. After two days I had heard no reply so I sent off another one which apparently did not reach the bureau either. I then wrote an airmail letter that reached the bureau about ten days after my discovery. So I was a little bit — how shall I describe it (laughs) — on edge for ten days.

Q: Are any of the comets which you have found periodic?

A: I believe most of the comets that I have found are what one might call long period comets. Their returns will be many hundreds or thousands of years from now. 1979*l* is the closest to being a periodic comet, and it has a period of about 306 years.

Q: It is entirely possible then, that 300 years down the road, somebody will re-acquire this comet, perhaps for a moment have the heart beat faster, thinking something new was found, and then they will contact the Central Bureau for Astronomical Telegrams and be told that the comet in question is Bradfield 1979*l*.

A: Yes, I suppose so.

Q: Can you tell me how you felt about your most recent comet, how you felt when you found 1980*t*?

A: When I picked up my most recent comet, I must admit that I was really amazed. There it was, in all its glory, a comet with a tail, something I really did not expect. After all, I had been in the process of packing up my gear about to leave for home. But because I had not covered a particular part of the sky, I thought I would use my small binoculars to simply scan the area. Suddenly I became aware of some little faint thing in the field of view. I was not quite sure what it was. I immediately went to the telescope, which was still on the stand, aimed it and "bing" there it was: a comet. I fell back in amazement, almost. The excitement was tremendous.

My only concern at the time was to get a reasonably accurate position so I could compose a meaningful telegram, because it was twenty or thirty minutes into twilight and the sky was getting brighter and brighter. I was rather in a panic, to put it plainly, to get its position, which I managed to do.

After I sent the telegram away, I told my friends in the Astronomical Society. The first person I rang was Ralph Sangster. He is the man who built my comet-seeking telescope and actually used it for a while. When he hears of my discoveries he is very happy because he feels that he has achieved something through building the telescope. Though Ralph is getting on in years, he retains a great interest in astronomy and becomes very excited when he hears the news. In fact it has got to the stage now that when his phone rings, and he realizes it is me, he says "What, another comet?" I guess he expects that there will be a twelfth some time soon.

****

Time has flown. You are invited for lunch, meet Mrs. Bradfield and one of their daughters. Conversation ranges from amateur astronomy to full immersion baptism, from the state of the world to the influence of labor unions in Australia. Suddenly it's time to leave. Bill drives you to the airport. Adelaide, Australia, in the late afternoon reminds you of home, of California. The clouds are beginning to dissipate. Yes, he will be out searching tonight. This very night may yield his twelfth discovery. Together you walk to the gate for the Melbourne flight. Then it's goodbye. It is as if you had known him for a long time through his discoveries.

By the time you land, an hour later, you have firmly resolved to join the search, to dream the impossible dream: your own comet.

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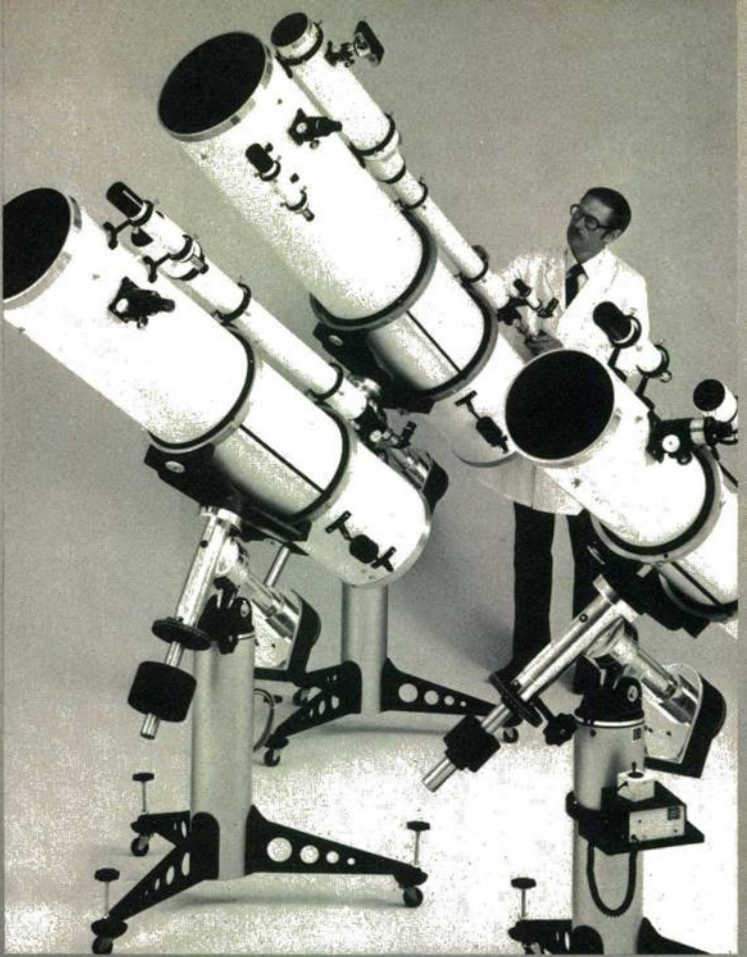

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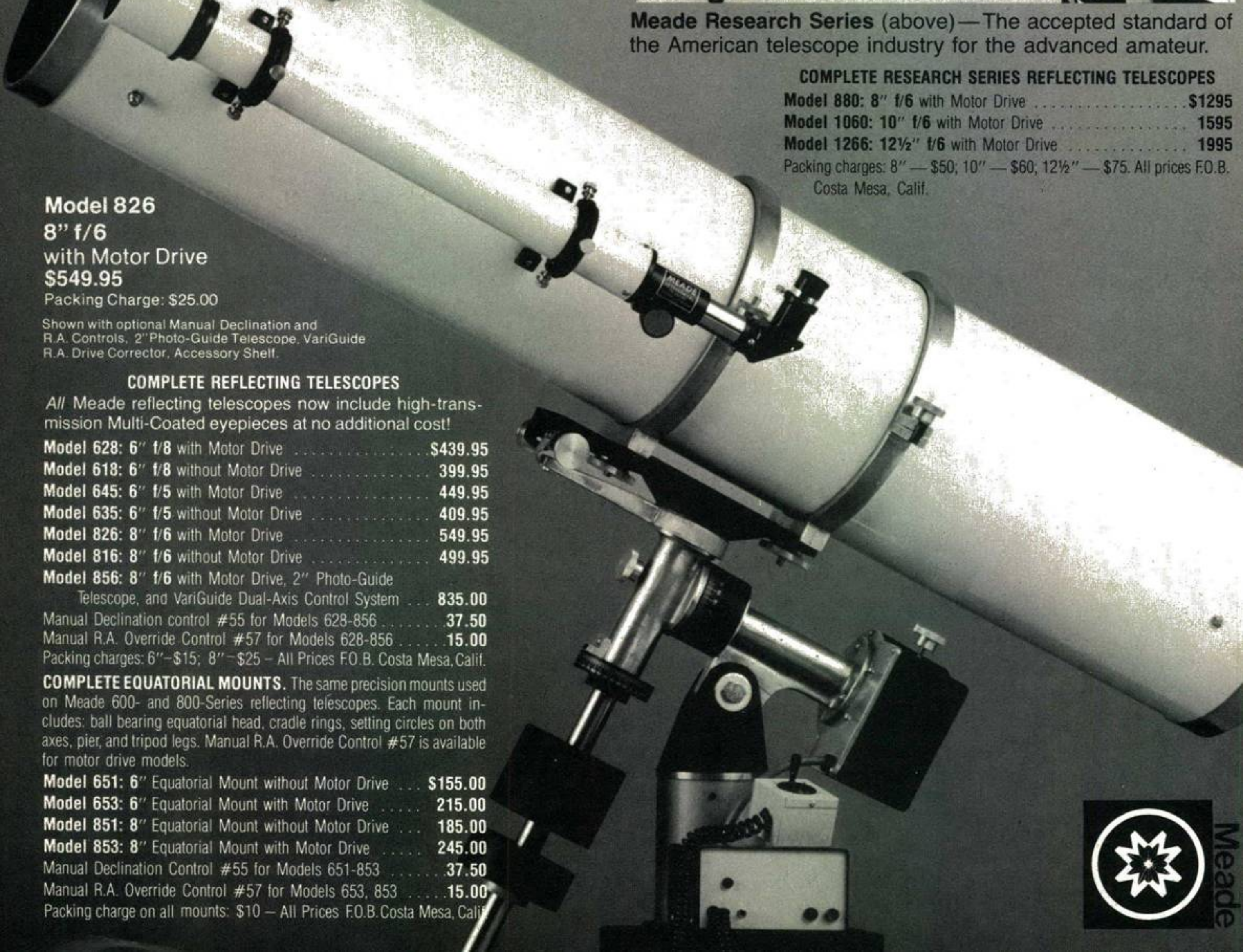

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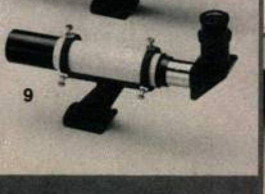

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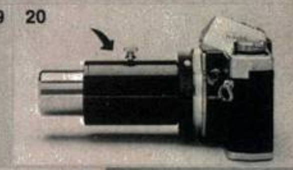

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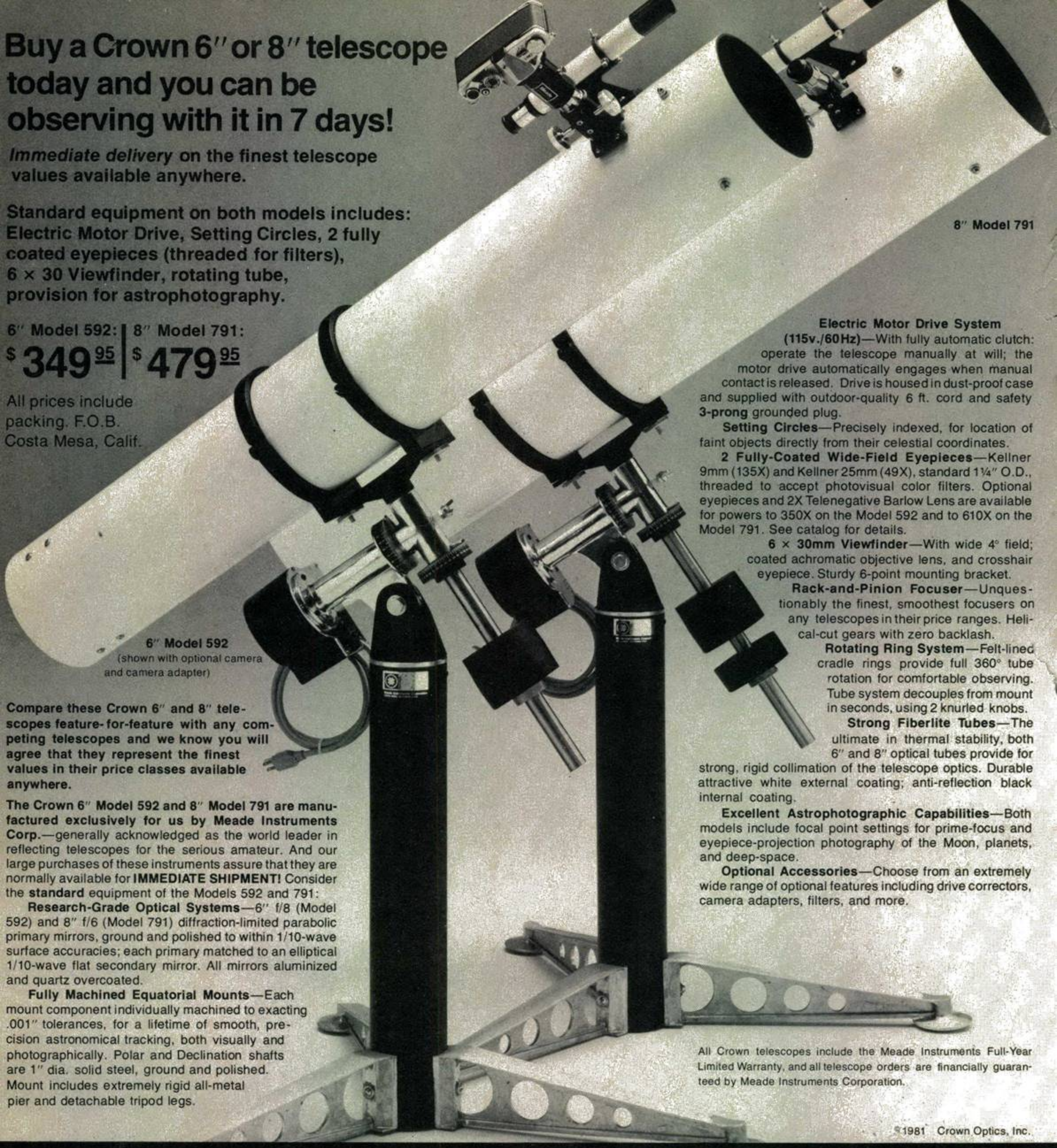

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photography in astronomy

by
Dale Lightfoot

You waited patiently for that perfect night to try out your special-order astrofilm, and it paid off. Your equipment worked well all night, and the extra time you spent carefully aligning the polar axis resulted in almost error-free guiding. After anxiously developing the film, while reciting Murphy's Law backwards, you inspected the negatives and found that — Eureka! — the developing was perfect and even pinpoint star images were recorded at the center of the field. Was Murphy wrong? You won't know until the finished prints are in your hands, because until that time Murphy's little gremlins still have a chance to ruin your best attempts at astrophotography.

"But printing is the easy part," you might argue. "If I come up with perfect negatives, then I should always be able to make beautiful prints without much trouble."

Normal Printing

While it's true that you can't make perfect prints from poorly developed or poorly guided negatives, it's just as true that a print made without using the proper darkroom equipment and techniques — no matter how good the negative is — will invariably be a disappointment. Any astrophoto, regardless of guiding and development, can only be as good as the paper it is printed on — and the effort put into that printing.

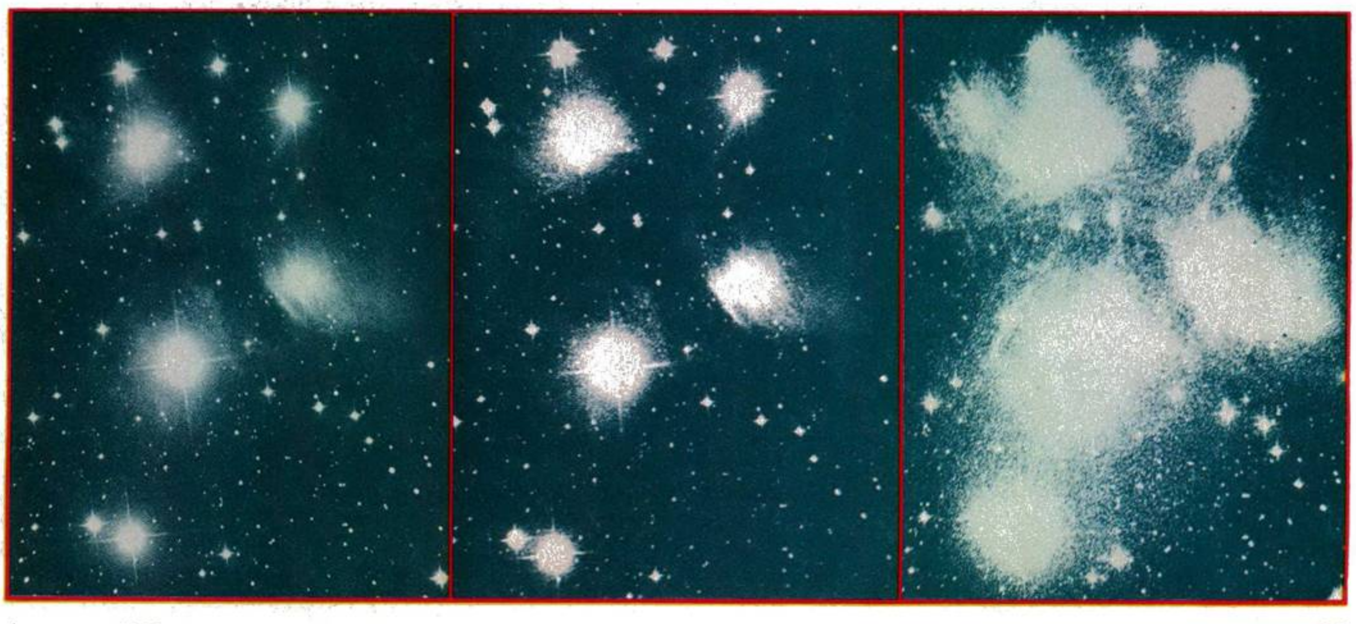
Although normal printing is not difficult, the detail you see on your negative may defy your best attempts to make them into 8" x 10"s if you don't use the proper paper. When selecting photographic paper there are two things to consider: type and contrast grade.

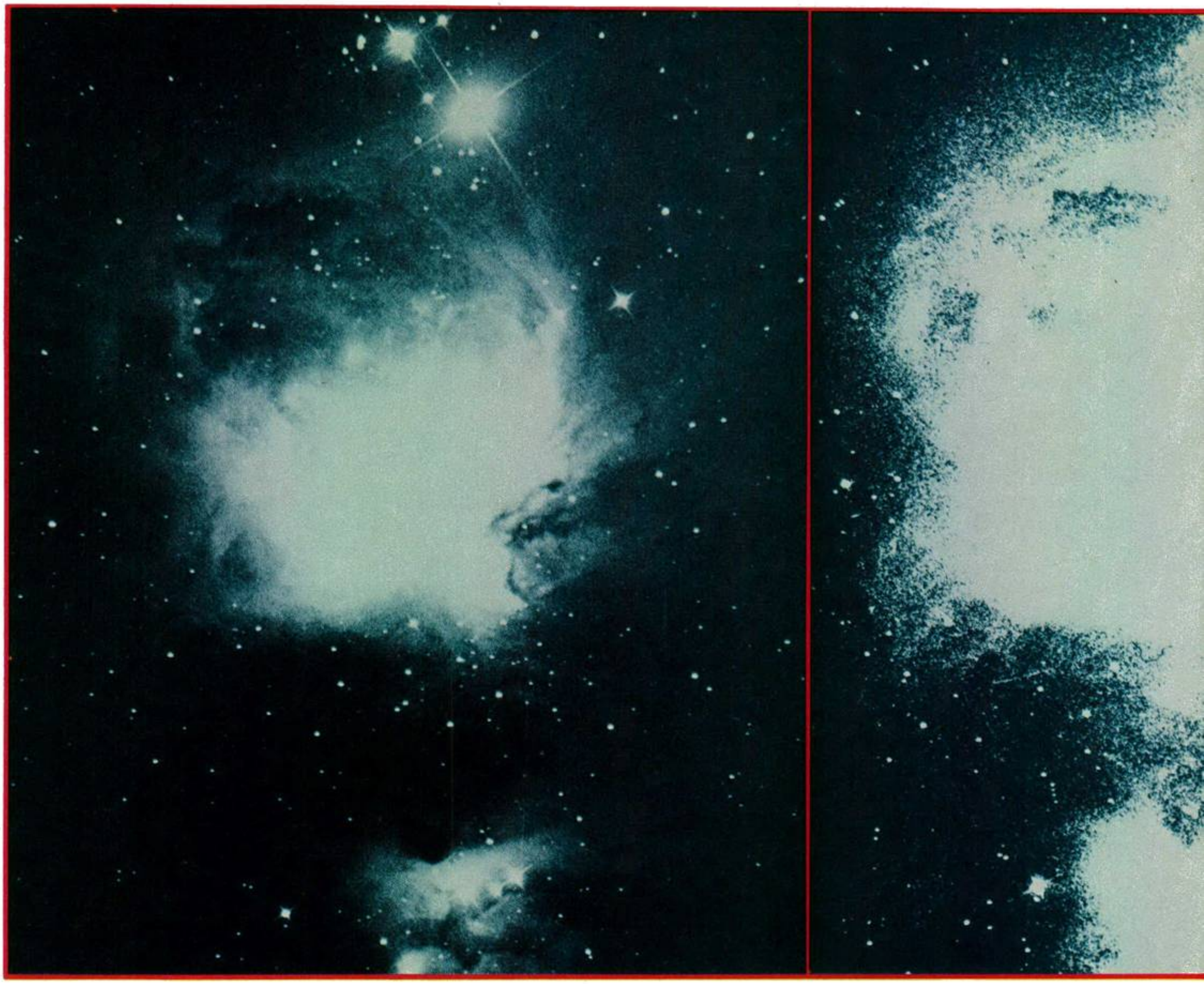
The type of paper denotes what kind of surface it has — glossy, matte, or silk finish. Glossy paper is the best for printing astrophotos because it shows finer detail than the others. It is alarming to see (or not see) the fine details of your negative hiding between the bumps and ridges of silk-finished prints.

The paper grade tells you the contrast range: grade 1 is the least contrasty, and grade 6 is the most. Contrast is the difference between the lighter and darker areas. When printing astrophotos you want as much of it as possible between the dark background sky and the lighter nebula or galaxy.

You can darken the background of your print in three different ways: give the paper more light, expose it longer, or lengthen its developing time. But there can be problems with this process. When you use a lower grade paper like the kind most commonly stocked in amateur darkrooms, your nebulae will darken at the same time

These three images of the Pleiades (left to right) illustrate gains afforded by the following techniques: printing the negative on high contrast paper, photocopying the negative, and using contrast enhancement. All photos are 35-minute exposures on 103a-F film developed in D-19 for four minutes at 68°F.





Above left to right: Three images of the Orion Nebula made with high contrast paper, the contrast enhancement technique, and the unsharp mask. Each is a 25-minute exposure on 103a-F film developed in D-76 (1:1) for 15½ minutes at 70°F.

your background does. You may even watch in dismay as they fade away into the deepening black. The best way to solve this problem is to use a higher contrast paper such as grade 5 or 6. These will enable you to create a print in which the nebula or cluster stands out from the dark background of sky.

One product that produces excellent results is a new Unicolor glossy grade 6, RC paper. RC stands for resin coated, which means you can air-dry the paper and it won't wrinkle. Glossy papers usually carry the designation "F" to denote that type of surface. Unicolor makes the only grade 6 glossy RC paper. Anything over grade 4 is not easily found in most photo stores so you may have to special order a package. However, the benefits of higher contrast paper are worth the wait.

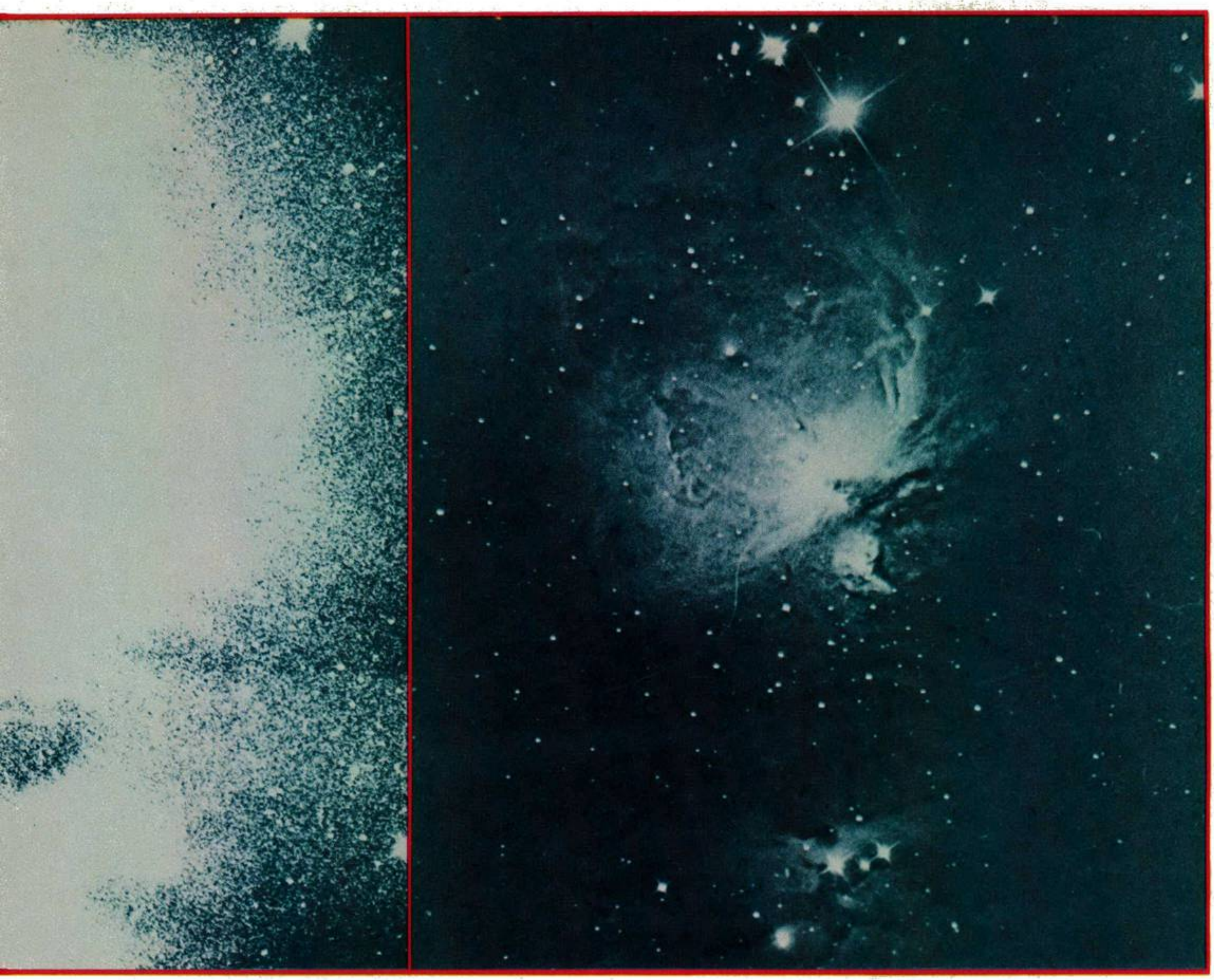
Special Printing

Now that you have high-contrast printing paper nothing is impossible, right? Not necessarily. Even though your correctly selected paper will make the object stand out better against a nicely darkened background, it will not work miracles. Some astronomical objects are hopelessly dim, especially in amateur-sized instruments, and although the higher grade papers help, the object could be of such low contrast that it won't bloom forth the way you would like. Cheer up. All is not lost; there are other ways of exploiting your negatives.

Photocopying

The easiest method for increasing contrast in a print is by photocopying it — taking a picture of your completed high contrast normal print. All you need is a camera with a light meter and cable release, a tripod, a couple of photoflood lamps for a source of illumination — table lamps will do — and, of course, film.

Once you have your camera on the tripod and your original print on high contrast paper positioned in front of the camera, you are ready to begin. Place the lamps so they illuminate the print from both sides. Don't let any shadows fall on the print, and determine the exposure with your light meter just as you would do for any snapshot. Also, be alert for any surface reflections from the lights. These can ruin the photocopy if they are near the lens. A lens hood made out of black construction paper rolled into a tube and placed over the lens will eliminate the reflections. Use a medium to fast film, such as Kodak Plus-X or Tri-X, with the camera lens wide open. This will enable you to use as short of an exposure as possible. With everything ready and the print nicely framed in the viewfinder, depress the cable release: "click" goes



the camera and you are now finished copying that print. Repeat the process for other prints and then develop the film. On your new negatives you'll see ultra-high contrast images of the objects on your prints.

You are now ready to print again — but remember to print these new photocopied negatives on the same high contrast paper as before so you can reap their full benefits.

Photocopying is great for vividly bringing out what already shows — however dimly — on the normal print. But, as with most everything in life, you must take the good with the bad. In addition to increasing contrast you also increase graininess of the print when you photocopy and therefore wipe out any subtle, soft tones or details which are found in normal prints. You'll have to decide which trade-offs will give you the results you want.

Contrast Enhancement

If photocopying isn't quite what you're shopping for, you can try another technique that brings out detail you can't even see in your negative. What! How can you print something that just isn't there? The question is somewhat misleading because, whether you see it or not, your negatives have information locked up in their grains that is not visible to your unaided eye, but can be coaxed out.

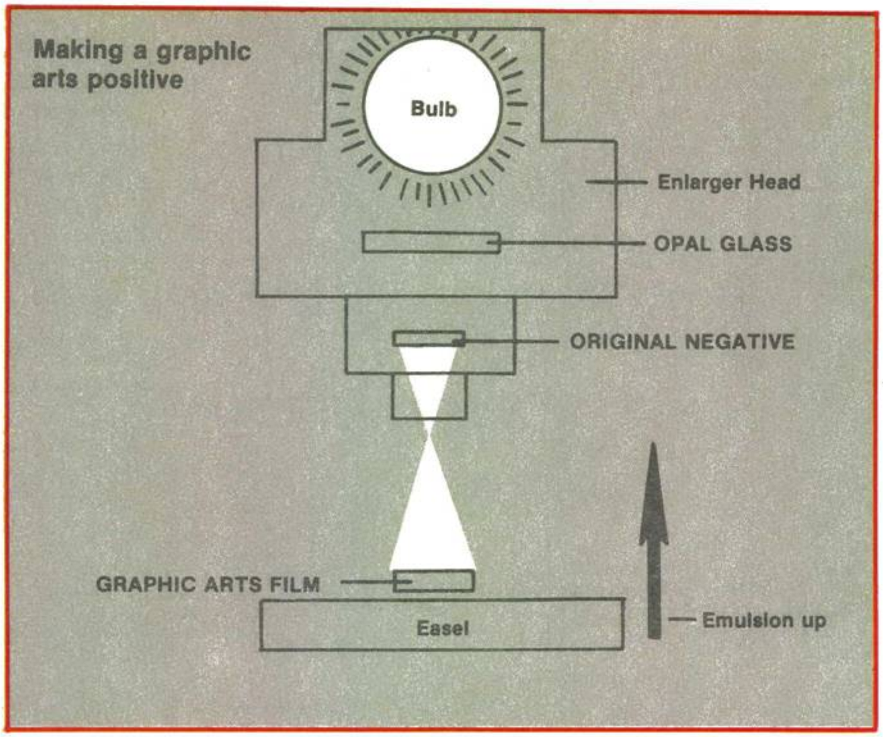
Before starting you will need, in addition to an enlarger and the usual darkroom equipment, a piece of opal glass or a similar light diffuser available from camera shops and glaziers, and some graphic arts film.

Opal glass is milky-white and diffuses or scatters light that passes through it. When scattered light passes through a negative it allows only the grains at the surface of the film's emulsion to be projected. Parallel beams of light coming from a bare enlarger bulb project every grain from the entire thickness of the emulsion. Since surface grains contain all of the faint detail of an object, and the rest of the grains throughout the emulsion contain mostly sky fogging and background "noise," the use of a light diffuser allows you to project faint nebulosities — without their detail being blotted out by sky fog — onto the graphic arts film.

Graphic arts film is a special type of high-contrast copy film which is usually purchased in sheets. The best seems to be Agfa type Fo, which can be purchased from most commercial photography stores. This film comes only in large commercial sized sheets, but most stores will cut it into 4"x5" pieces for you. If you can't find Agfa, then try for the more popular Kodak Kodalith graphic arts film found in almost any camera store.

The enhancement process is simple if you follow these three steps:

Step #1. Make a graphic arts positive from your original negative. Before you start, place your original negative in the enlarger and position the opal glass so that it will diffuse the light before it reaches the negative. Adjust


Making a graphic arts positive

the enlarger so the image projected onto the easel is about the same size as the original negative — a 1:1 ratio. Cut a piece of film just large enough to cover this small projection and expose it, emulsion side up, just as you would a sheet of photographic paper. Although these films are most often used with their own special developers, you can get good results with normal print developer such as Dektol.

Exact exposure and developing times may vary according to enlargement size, developer temperature, and other variables which never fail to make themselves known. However, with a 1:1 enlargement ratio, an exposure of 25 to 30 seconds at f/11 will get you in the ballpark.

A good rule of thumb for developing time is to allow each positive to get fairly dark — always just a little darker than you think it should be. After fixing, you should have a small, transparent positive that looks very much like a normal print and which, upon completion of Step 2, can be mounted to make a first-rate black-and-white slide — a hidden bonus! Before beginning Step 2, remove the opal glass; it has served its purpose.

Step #2. Make a graphic arts negative from your new graphic arts positive or black-and-white slide. Place the emulsion side of the positive against the emulsion side of another strip of graphic arts film and make a contact copy — make sure that the positive is on top. If you don't have a contact frame, sandwich the two under a piece of clear plate glass to hold them flat. Again, exposures may vary, but with the enlarger lens placed about 12" above the easel, start with an exposure of 10 seconds at f/8. The rule of thumb for developing these negatives is to leave them in the developer until their backgrounds *just* start to darken all over. If they are taken out while the background is too light, they will look like a photocopy — increased contrast but no "invisible nebulosity."

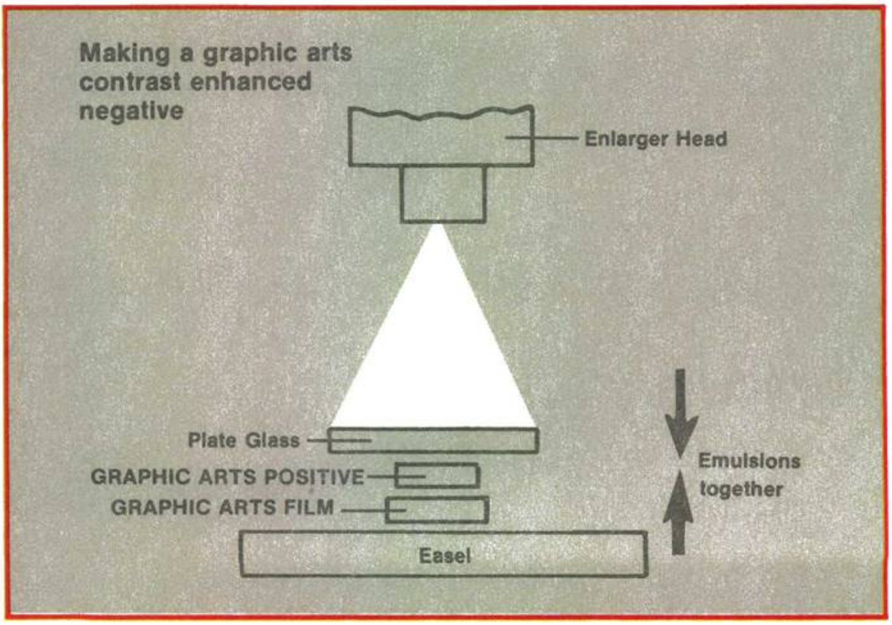
Step #3. After the negatives from Step 2 are fixed and dried, you are ready to print. Place them in the enlarger just as you would any negative (this is why you kept them small), and print them onto — you guessed it — high contrast printing paper. You'll see the nebulosity pop out at you. Now you can allow the background to get blacker than ever before and still end up with much more nebulosity than with the normal print, or the photocopy process. You must always be on the lookout for gremlins, however, because darkroom sloppiness will be magnified by this technique.

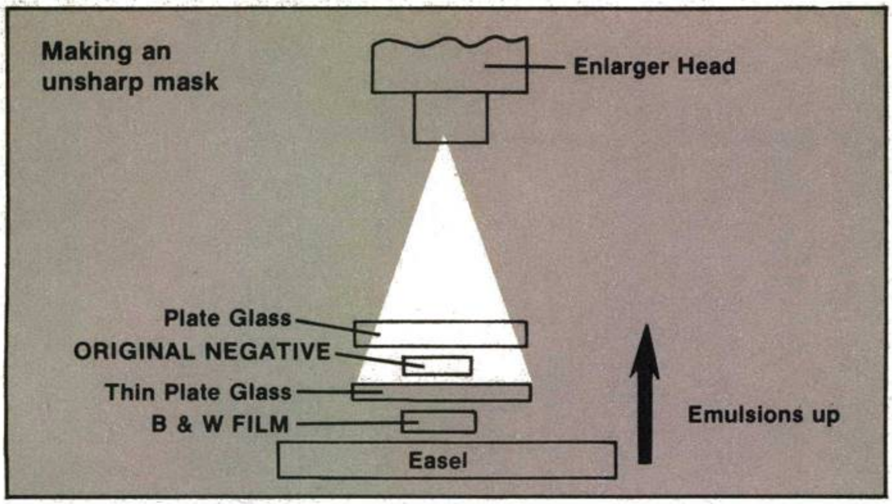
It all sounds so good, you're probably waiting for the catch. As with photocopying, contrast enhancement increases graininess and obliterates subtle, soft tones. It will also bring up vignetting and scattered light effects that you don't want enhanced. You probably won't notice these problems as much — you'll be too busy exploring the hidden detail that just popped out from your negatives.

Unsharp Masking

Just as faint outer nebulosity is usually present in a negative and needs to be coaxed out, so are inner details — even though they appear to be hopelessly overexposed. But you'll need a way to keep the faint areas from turning completely black, while bringing out subtle detail in the bright areas. The first step is to make an unsharp mask. Although this sounds rather strange, it is nothing more than a slightly blurred or unsharp positive on film with the darkest parts in the original negative becoming the lightest on the unsharp mask. When the mask is sandwiched and lined up with the original, the light areas of the mask allow more light to penetrate the densest areas of the negative — essentially "burning" them in. This darkens the overexposed white area so the detail inside it develops.

In the rest of the photo, the faintest nebulosities will not record on the unsharp mask and will be unaffected. Faint areas will show up as well as ever on the finished print while, at the same time, bright areas that were


Making a graphic arts contrast enhanced negative



overexposed to record the faint detail will show their delicate internal structures.

Before you begin the masking process, have on hand a fresh roll of black and white film, such as Plus-X, to make the mask on. Since most astrophotographers deal with 35mm films, the masking technique must be modified very slightly from the method used by professional observatories that work with large photographic glass plates. The process is as follows:

Step #1. Make your unsharp mask by contact printing. Leave a slight separation between the original emulsion and the blank film to produce an unfocused or soft image. How do you get that separation?

In professional observatories, technicians place a fresh photographic plate, emulsion side up, opposite the light source from the original plate also with its emulsion side up. Before light can expose the soon-to-be mask, it will pass through the glass backing of the original and throw off the focus of the new image. This works fine for glass plates, but what about 35mm film?

You can imitate the professionals by sandwiching a 1/16" thick piece of plate glass between the original negative and the fresh film. This will shift the light out of focus as it passes through the plate glass on its way to the film — just as with a photographic plate.

Follow this procedure: Turn off the darkroom lights and place the fresh film on the enlarging easel emulsion side up. Put the glass on top of it and place the negative, emulsion side up, on the glass. Use another sheet of glass, which can be thicker, to hold the whole affair down flat. Now you're ready to expose.

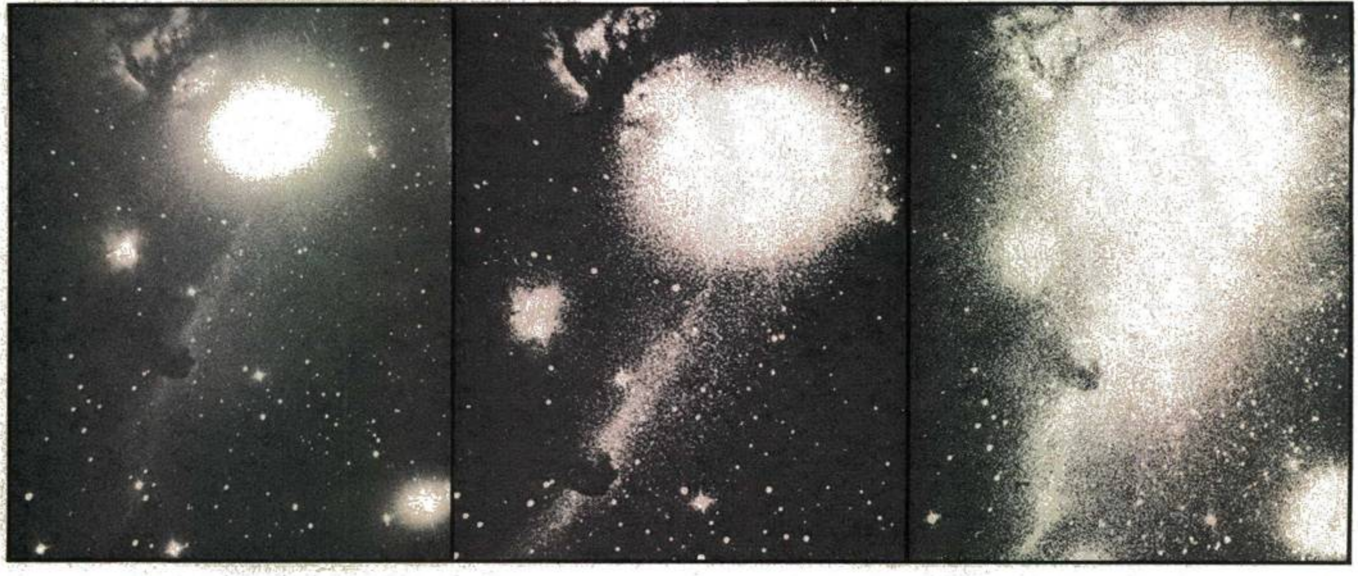
The background of the mask should be of medium density for best results; an exposure of 1½ to 2 seconds on Plus-X used with an enlarging lens at f/22 should be about right. Before developing, make at least two more masks — one timed either side of the trial exposure to insure that at least one comes out perfect — and develop them all according to manufacturer's charts.

Step #2. You are now ready to print. After aligning the original and the mask as closely as possible, sandwich them together in your enlarger's negative carrier and print them onto high contrast paper as you would a normal print — just remember to add more exposure time and/or light to compensate for the darker background the mask has created.

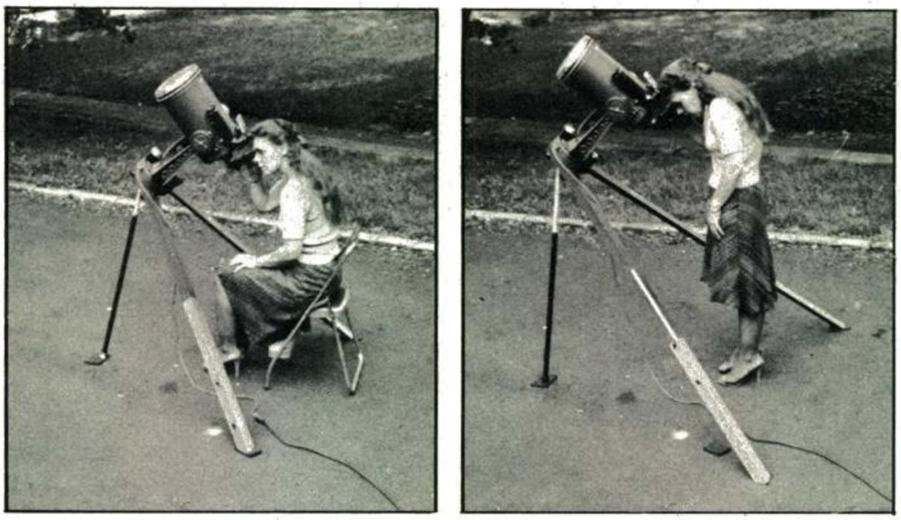
Just as with contrast enhancement, sloppiness will magnify your errors and affect the evenness of the background. This technique has one catch — it is useful only on objects that are bright enough to become overexposed, and these are few in most non-professional telescopes. Observers with large scopes, however, can use the unsharp masking process with great success.

By now you should be able to answer the questions posed at the beginning of this article. You can turn out great astrophoto prints, but not solely because of good negatives. Your darkroom technique is also very important. Just as you wouldn't want to use cheapo brand eyepieces on first-rate optics, you defeat your purpose if you use the low-contrast paper or haphazard darkroom work on carefully guided, first-rate astronegatives.

The astrophotos you make are your own creations and the end product is judged mainly by how you think it should appear. Do you want ultra-contrast prints or prints that show subtle middle tones? Should you bring out invisible nebulosities or look deep into the interior details of an object? It's all up to you.



Notice the varying detail in these three shots of the Horsehead Nebula. From left to right: a normal print on grade 6 paper, a photocopied original, and a contrast enhanced original. All are 30-minute exposures processed for four minutes in D-19 at 68°F. Photos in all three series taken by the author through an 8-inch f/5 Newtonian.



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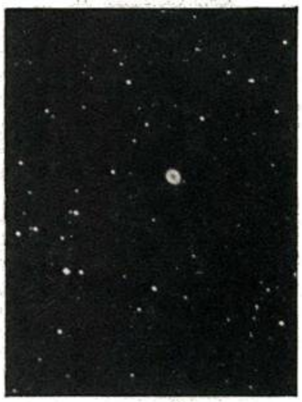

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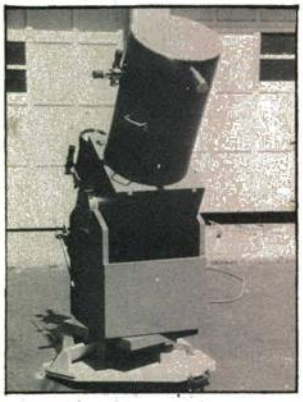

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equatorial platforms

Wouldn't it be handy for astronomers if the Earth didn't spin? Just imagine pointing your telescope at the sky — with no drive — and looking at the never-moving stars. It would certainly make building telescopes a lot easier, too, with none of the complications of equatorial mountings.

Well, maybe there's an easier and less futile way than crying, "Earth, stand still!" — and with fewer cosmological implications. What would happen if you built a platform, something like a tabletop, and turned it slowly in the direction *opposite* the direction of Earth's spin? You could then "de-rotate" our planet — and to a camera or telescope on top of the platform, the sky would appear stationary.

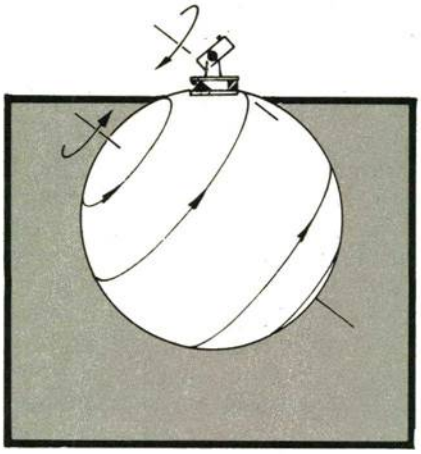
It's actually not too difficult to build such a platform and only moderately difficult to drive it smoothly against the rotation of the sky. In the last few years, mechanically minded observers have tried several ways of doing this. And they work.

"Phooey on that! Give me a reliable equatorial mounting anytime. Why put a lot of effort into building a platform when I can build a good mounting instead?"

Granted: for the very best tracking, you can't beat a well-made equatorial mount. The advantage equatorial platforms offer is universality: once you have an equatorial platform, it will de-rotate the sky's motion for anything you put on top of it. You can stick your low-cost thin-mirror Dobsonian on top, and even take guided pictures with all that aperture. And the platform is low to the ground, stubby, and thus intrinsically stable.

For eyeball observing you can forget the platform and take just the telescope. You can't take the equatoriality out of an equatorial mount quite so easily.

"Where's the catch?"



There are plenty of catches. Right now, equatorial platforms are new — if you want to try one, you're going into new territory. Nobody has years and years of experience building them, and the good designs haven't been separated from the bad. You'll have to play the inventor yourself, at least to some degree.

Equatorial platforms also provide only one motion — R.A. — and the declination motion isn't easy to fudge. For guiding photographs, then, they don't work as well in some parts of the sky as they do in others. But the parts of the sky where they do work well are on or near the meridian and along the celestial equator — the best areas of the sky for guided photography.

"Explain to me how they work. I'm really not convinced yet. How can something 24 inches square and 6 inches high track the sky?"

The easiest way to see it is to imagine a split-ring equatorial mounting — like the one the 200" Mount Palomar telescope rides in. The whole thing turns in the opposite direction the Earth turns. The axis of the rotation passes through the center of the upper ring and through the pivot bearing at the bottom.

Now, just cut off all the superstructure and build a flat top on it. The principle is the same — everything rotates in the opposite direction of the Earth's spin. When you put a telescope on top of the platform, it tracks equatorially. Except, of course, for the disadvantages we mentioned before.

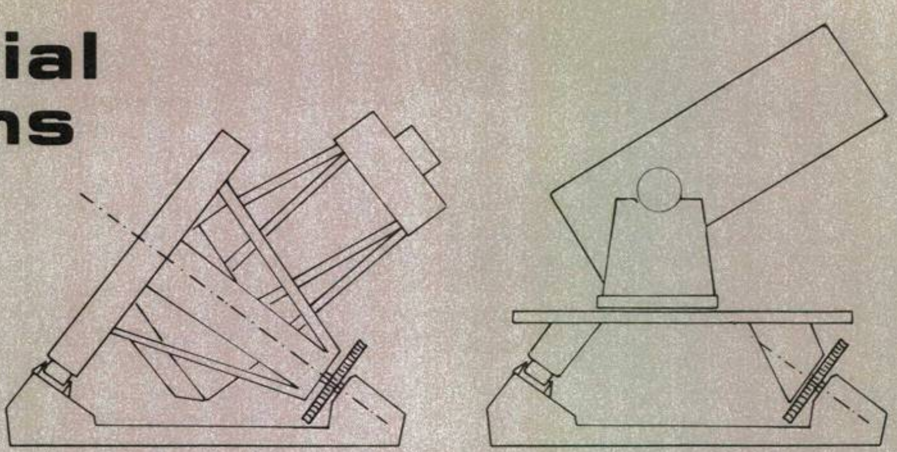
There are lots of different ways to accomplish the rotation about the polar axis. The easiest to understand, and probably the best for supporting a heavy telescope, is derived directly from the Palomar-style mounting. You attach part of a large ring to the bottom of the platform, provide smooth-turning rollers for it to run on, and, of course, give it a bottom bearing to pivot around. You can put a drive at the lower pivot bearing, or drive the large ring at the north end directly. Either way works — it's mainly your choice of mechanical convenience.

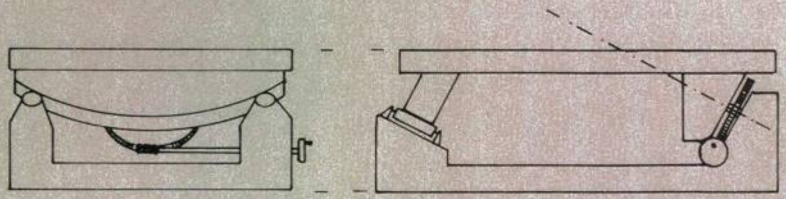
In another method, invented by Adrien Poncet who lives in Jura, France, the platform rotates by sliding on an inclined plane. If you remember your geometry from high-school, the two pivot points must move in a circle on the inclined plane — and the axis they rotate about must be normal to the plane. This type is really easy to build, but the going gets tough if the platform has to carry a lot of weight. You have to push awfully hard to make it turn, and it may stick and bind. Teflon® plastic — the same stuff on the bottom of non-stick frying pans — slides very smoothly on Formica® counter-top plastic. For light telescopes and cameras, there's a lot to recommend this scheme. Plus, it's a very elegant way to produce a circular motion.

"And it works?"

It does. And there's even another way thought up by Australian Graeme White, although nobody seems to have tried it yet. Suppose you built a big wooden box, then cut it in half — not parallel to the side, but at an angle equal to your latitude. Put hinges along one side and a jack mechanism on the other side. What happens when

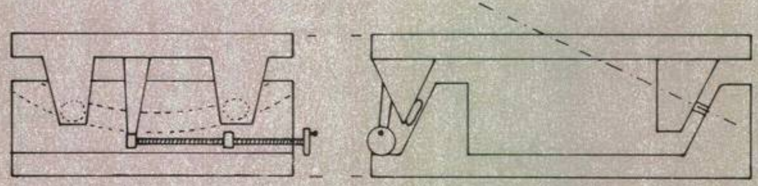
equatorial platforms

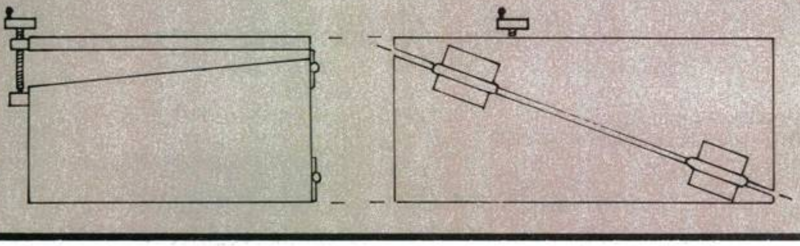




Palomar Style
the platform turns on rollers driven by a conventional drive gear

Poncet Style
the platform slides on plastic-on-plastic, driven by tangent arm





Box Style
a hinged box opens, driven by a jack screw; the platform is the top of the box

you operate the jack?

"The box opens."

Not only does it open, but the top part rotates, right? The angle between the bottom and the top increases.

"So it does. But how would I use it?"

If you align the box so the hinges point to the pole star, the top of the box becomes an equatorial platform — *Voila!* Of course, as the box opens, the top tilts. All equatorial platforms start to tilt after a while. Tilting becomes troublesome about 30 minutes from dead center because your telescope or camera can fall off the platform. If you start 30 minutes before dead center, then track through it, you get about an hour. You'd get considerably more time with a stubby telescope.

"Okay. Let's get some details. How does the drive on this thing work?"

You can build them two ways. The first is with a conventional drive gear attached to the pivot point. This works best on the Palomar-style platform. You can also drive one of the rollers on a Palomar platform. The big bearing circle will then roll along on top of it.

Another method — used by most of the people who have built equatorial platforms so far — is a tangent-arm drive. The platform carries an arm with a split nut on it; that engages a threaded rod turned by a motor — or by hand if you want to turn it by hand.

"So the threaded rod pushes the nut in a straight line and the platform turns around the polar axis? And the telescope on top of the platform tracks?"

Exactly. The radius of action, R, that you're turning is the distance from the pivot point to the split nut, D, multiplied by the sine of your latitude, or:

$$R = D \sin L$$

The circumference of the circle you turn is 2 times pi times R, so the distance it must move in one minute is:

$$d = 2\pi R/1436$$

because there are 1436 minutes in a sidereal day. All you do then is choose a motor speed and thread pitch to produce that much motion.

"I'll have to think about that some."

Well, remember, this is a wide-open field. You can experiment some —and perhaps you'll be the one to come up with a better way. Just think: An amateur astronomer in England mounted his whole observatory on an equatorial platform.

— *Richard Berry*

Celestron 11 Schmidt-Cassegrain Telescope

LARGE-APERTURE, MULTIPURPOSE TELESCOPE

The Celestron 11 is our newest large-aperture telescope. It has features that have made other Celestron telescopes famous: large, diffraction-limited optics; a stable sandcast fork mount; a worm gear drive system and super portability.

The Celestron 11 was designed to fill the gap between the Celestron 8 and Celestron 14. Accordingly, the Celestron 11 is positioned between the C8 and C14 in price, portability, aperture and capability.

The heart of the C11 is an 11-inch (280mm) clear aperture optical system. The optics are diffraction limited and of f/10 focal ratio. The optical tube assembly is supported by a sand-cast fork mount which rapidly detaches for easy transport to remote locations.

With the Celestron 11 we're confident you can find many applications:

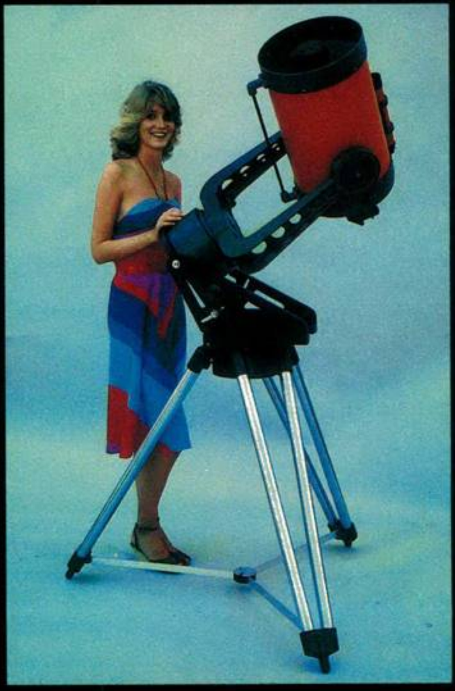
- Astrophotography — The C11 has a huge light-gathering power, 2800mm of focal length and a stable worm gear drive for quality photographs of the sky.
- Astronomical observing — Despite its huge aperture, the C11 is easily transportable to remote star party locations, and you don't need a truck to haul it around, a compact car is all that's needed. The 11 inches of aperture will give such spectacular views of your favorite deep sky objects that you'll never want to use a smaller telescope again.
- Telephoto Photography — The 2800mm of focal length and moderate, f/10, speed allows the telephotographer to capture rare animals and distant events with ease.
- Astronomical Education — Here is a telescope that can handle many student research projects and astrophotography efforts. While it is sufficiently portable to easily take on class field trips, the C11 is large enough optically to make a student's first impressions of the planets and deep sky objects exciting.
- Research in Science and Industry — Researchers in laser physics, cinematography, solar energy, satellite tracking and observatory site selection, to name a few applications, will find that the diffraction limited optics and compactness of the C11 make it a very attractive and extremely affordable piece of research or surveillance hardware. Celestron telescopes are incredibly versatile, with applications limited only by your imagination.

OBSERVING WITH THE CELESTRON 11

Observing is a pleasure with the Celestron 11. It collects 1,778 times more light than your unaided eye to give you the bright images and resolution you'd expect with 11-inches of aperture and 2,800mm (110-inches) of focal length. Its compact physical nature not only makes the Celestron 11 easy to move around but also easy to use — all the controls and finderscope are within easy reach.

With the Celestron 11, the solar system becomes a *place* with which you can become familiar, rather than just names in a textbook. With the optional 5-inch off-axis solar filter you may leisurely study the granulation and sunspot structure of the sun's turbulent photosphere (visible surface). The inner planets have easily identifiable phase changes; and under clear, steady skies at high elevations, faint violet markings can be occasionally glimpsed on Venus. Jupiter and Saturn are presented to you with image scale and clarity that easily permit serious study and photography; the details and colors on these gas giant planets are breathtaking. All the other objects from the Moon, Mars and outer planets to the ephemeral comets and faint asteroids are targets for your study and appreciation.

M51 C11 Photo



C11 Telescope on optional Wedge and Tripod

Deep Sky Observing — viewing the stars, galaxies, clusters and nebulae beyond our solar system — with the Celestron 11 is an exciting pastime. Objects which appear amorphous when viewed through smaller telescopes will, with the C11, appear to have structure and definition. Color is visible in some of the smaller planetary nebulae, and smaller galaxies, such as the companions of M31, M32 and NGC205, now have a definite nucleus and surrounding halo of star-stuff. Globular clusters are better resolved and fainter stars are visible when compared to views through smaller instruments. With an instrument of such capability the 2-inch diameter optional oculars allow spectacular wide-field views of your favorite deep sky objects.

Basic C11 Telescope Specifications

Standard features in the base price:

The base price Celestron 11 is a complete working telescope and includes: Optical Tube Assembly, Visual Back-1¼", Star Diagonal-1¼", 10 X 40 Finderscope, Fork Mount, Setting Circles, Electric Clock Drive, Clock Drive Cord, Piggyback Mount, Tele-Extender, T-Adapter, Counterweight Bar Assembly, 40mm-1¼" Ocular, 25mm-1¼" Ocular, 12mm-1¼" Ocular, Lens Cap, Carrying Cases, and Instruction Manual.

BASIC C11 SPECIFICATIONS

Optical configuration	Schmidt-Cassegrain
Clear aperture	11 in. (280mm)
Effective focal length	110 in. (2800mm)
Photographic speed (focal ratio)	f/10
Highest useful visual magnification	660x
Near focus (approx.)	70 ft. (21.3m)
Resolution:	
Arc seconds (Dawes' limit)	0.4
Stellar magnitude limit	14.5
Image scale — degrees per inch	0.52
Film coverage (on 35mm format) at:	
100 feet	1.2 x .79 ft. (36 x 24cm)
1000 feet	12 x 7.9 ft. (3.6 x 2.4m)
Secondary obstruction	13% (4 in. dia.)
Mounting (equatorial wedge optional)	fork type
Slow motion controls, both axes	manual
Electric clock drive — synchronous motor, solar rate	110v, 60Hz, 2 watts
Drive gear diameter	6⅞ in. worm
Polar axis diameter	2¼ in.
Setting circles	Dec. 5⅛ in., R.A. 8¾ in.
Optical tube dimensions	12.5 in dia., 23.5 in. long
Optical tube weight	27.5 lbs. (12.5 Kg.)
Telescope size, swung down	13 in. (33cm) x 18 in. (46cm) x 30 in. (76cm)
Telescope weight — complete	57 lbs. (26 Kg.)
Shipping weight — (three cartons)	115 lbs. (52 Kg.)

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New Thoughts on Solar System Formation

Two scientists at NASA's Ames Research Center have contributed significantly to changing scientific thinking regarding the origin of the solar system.

Scientists have long thought that the solar system originated from a thin and cold cloud of interstellar matter that contracted into a more dense uniform cloud of hot gases and dust called the solar nebula. As the solar nebula cooled, mineral grains formed by condensation. The dust and grains aggregated into small, solid bodies, and these so-called planetesimals were consolidated into the planets, moons, comets and asteroids. According to this theory, the first formed planetesimals of the solar system should contain roughly the same proportions of the rock-forming elements as are found in the Sun.

Earlier studies found such a similiarity in a special class of meteorites called carbonaceous chondrites, once considered by scientists to be primitive or unchanged examples of these first formed planetesimals.

But new findings by Theodore Bunch and Sherwood Chang open the doors to new ideas about the origin of these meteorites and, therefore, about what happened in the earliest stages of the origin system.

The rocky pieces of matter that hold the clues to the origin of the solar system are called carbonaceous chondrites because they contain the element carbon, one of the building blocks of life. They also contain other building blocks — hydrogen, nitrogen and oxygen — and complex organic molecules. They are among the oldest rocks yet discovered, some over 4½ billion years old.

"They are like archaeological artifacts," Chang said. "Rather than reconstructing cultures, we are trying to reconstruct the origin of these bodies. By doing this, we can begin to reconstruct the origins of the solar system itself."

The researchers found at least three different kinds of clays in the carbonaceous chondrites. The conventional theory hypothesized that these clays formed by reactions between gas and dust in the solar nebula prior to consolidation into small bodies. However, the clays show no evidence of this gas/dust origin. Instead, evidence indicates they formed in ways similar to those of some clays on Earth. In some Earth environments, water reacts with some water-free minerals to form clays. The water dissolves and transports some minerals away, leaving clay minerals in their places. These sorts of processes could only have occurred on the parent body of the meteorite — perhaps a comet or asteroid — and could not have occurred in the solar nebula gas/dust cloud. The three different clays also had three different chemistries.

If the solar nebula theory were true, the clays should have a more or less uniform chemical composition. The differences in the clays could be readily explained, however, by the action of water on the minerals in the surface of a small body. The two researchers now believe the carbonaceous chondrites probably broke away from asteroids or comets after this process had taken place. Thus they are not unchanged, primitive samples of the past.

This raises the possibility that the water and some of water-soluble material, including organic compounds, in these meteorites were originally formed in interstellar space before the origin of the solar system. This requires that they were never evaporated in the solar nebula and managed to survive the processes of consolidation.

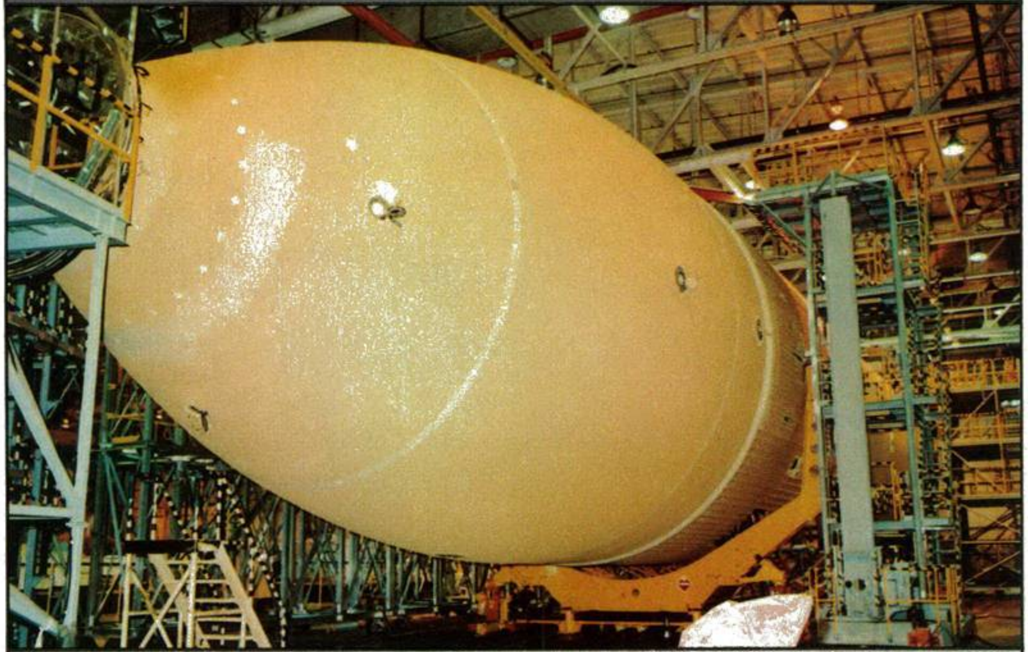
Thus, scientists may now be able to look backward in time and determine what was occurring in interstellar space before the solar system formed 4½ billion years ago.

"The mystery gets bigger as you expand your parameters," Bunch said.

Bunch and Chang suggest a new model labeled the cosmic raisin muffin model. When the solar system was forming, the bodies that aggregated at great distances from the Sun in the very low temperature regions — possibly comets — were composed mostly of ice mixed with rocky material and dust — clumping like raisins in a muffin. Nearer the Sun, as close as the outer regions of the asteroid belt, meteorites formed. They were made of mostly rocky matter with chunks of ice imbedded in them like raisins.

In many of the carbonaceous chondrites, the clays surround small regions of unchanged, relic material. The two scientists theorize

Unpainted Shuttle Tank Is 600 lbs Lighter



The external fuel tank for STS-3, the third flight of the Space Shuttle, will be light brown — the natural color of the spray-on foam insulation used on the tank exterior. Leaving off the white paint that covered the tank for the first shuttle flights will drop 600 pounds from the Shuttle's weight. Since the External Tank is carried almost into orbit, this adds almost 600 pounds to the Shuttle's payload capacity and saves several thousand dollars in manufacturing costs. NASA photo.

that the parent body, aggregated from both rocky and icy building blocks, was heated and caused the ice to melt and the water to react with rock minerals forming the clays. For some reason, perhaps a cooling of the parent body or insufficient water, alteration of the rocky matrix was incomplete, leaving relic islands of rock.

Bunch and Chang also theorize that during the aggregation of solid matter into asteroid-sized bodies tens to thousands of kilometers in diameter, the associated collision of building blocks with the growing bodies could have produced enough heat to melt the ice.

300 Million Light-Year Void Is Largest "Hole" in Space

Astronomers conducting a survey of galaxies have discovered a 300 million light-year gap of empty space that would ordinarily contain 2,000 galaxies the size of the Milky Way. The huge void offers astronomers a major new clue to the nature of the early universe and its evolution.

The researchers, who are studying the large-scale structure of the universe, said the diameter of the newly discovered region amounts to about one percent of the entire observable universe. It is much larger than previously discovered empty regions and bigger than the largest known cluster of galaxies.

Galaxies tend to clump together in clusters and superclusters, and until now, astronomers have paid limited attention to the vast regions outside the clusters.

Cosmologists speculate that both clusters and voids grew from what was once a smooth population density of galaxies. As time evolved, the population density increased in denser regions to form clusters and decreased in less dense regions to form voids. When the universe was only one ten-thousandth of its present age — about 1,500,000 years old — the density of stars and galaxies may have been nearly equal in the two kinds of regions.

The astronomers discovered the void when they turned their telescopes to the constellation Bootes and found the population density of galaxies to be at least 10 times less than expected.

Investigators are now trying to determine more precisely the boundaries of the void. They are also investigating the possibility that it holds matter in some form other than galaxies — perhaps tenuous gas or unusually small galaxies too faint to have been detected in the survey.

Augustus Oemler, Paul Schechter, and Stephen Shectman made the discovery using facilities at Kitt Peak, Mt. Hopkins, and Mt. Palomar Observatories.

Studies May Link CO_2 to Global Climate Changes

The first hint of man's ability to "terraform" planets may be showing up in a negative way on Earth. Two Columbia University researchers have detected a response of the global climate to an increase in manmade carbon dioxide in the atmosphere.

Carbon dioxide has been present in the Earth's atmosphere for at least two billion years. The atmospheric concentration of the gas has increased in recent years because of the burning of fossil fuels such as coal, oil and natural gas. CO_2 produces the "greenhouse effect," a phenomenon present on Venus that creates the high pressures and temperatures that make the planet unfit for human life. The effect appears when light from the Sun penetrates the Earth's atmosphere with little hindrance. The warm Earth re-radiates energy at much longer wavelengths. Increased levels of carbon dioxide, however, delay the escape of the long-wave infrared radiation from the Earth's surface, thereby raising average temperatures.

Scientists have long speculated that increased amounts of atmospheric carbon dioxide would raise temperatures. Until now, however, such predictions were in apparent contradiction with the gradual decrease of northern hemisphere temperatures observed since the 1940s.

George J. Kukla and Joyce E. Gavin of Columbia's Lamont-Doherty Geological Observatory said in their cautious report that their studies indicate the extent of pack ice around Antarctica during summers has decreased in the 1970s compared with the 1930s.

They also found that in the northern hemisphere the 1974-78 average surface air temperature in the zone of melting snow in spring and summer was up to 0.9°C higher than it was during the 1934-38 period — the warmest time of our century in the northern hemisphere.

In contrast, during fall and winter the temperatures in the latitudes between 55° and 80° north were approximately five degrees Centigrade lower than in the 1930s. If such an anomaly continues, it could have serious effects on the Earth's ecosphere and could greatly alter the Earth's climate.

"Our results suggest that studies of the highly variable components of the climate system such as snow and pack-ice fields and the associated surface air temperatures should be given priority in the search for early signs of a carbon dioxide effect," the two researchers said. They also said, however, that it is equally important to determine the cause of the recently observed cooling which is particularly strong in autumn.

"Since scientists are not certain how other changes in snow and sea ice areas and in surface temperatures can be explained by natural fluctuations or by processes unrelated to carbon dioxide, any conclusions on the relationship of the observed departures to a carbon dioxide increase must, at present, remain highly tentative," they said.

Have Two FK Comae Giants Coalesced into One Star?

Two astronomers believe they have discovered stars which were once double but have now coalesced. According to Bernard W. Bopp of the University of Toledo and Robert E. Stencel of the University of Colorado, three such objects — FK Comae Berenicis, UZ Librae, and HD 199178 — "may represent a new class of variables." The astronomers reported their findings in *Astrophysical Journal Letters.*

These FK Comae stars are giant-type stars ranging in spectral class from G2 to K0 — about as hot as the Sun, but larger and more luminous. They have small light variations (0.1 to 0.2 magnitude) over a period of a few days. Using the International Ultraviolet Explorer satellite, Bopp and Stencel observed these three stars and took ultraviolet spectra which indicate great chromospheric activity and many starspots. The stars' spectra at these wavelengths resemble the spectra of RS Canum Venaticorum stars — close, interacting binary systems.

The FK Comae stars also display exceptionally broad spectral lines. This implies extraordinarily rapid rotation. As a rapidly rotating star turns, one side of it approaches us very quickly while the other side recedes from us equally quickly. Light from the approaching half is shifted toward the blue end of the spectrum; that from the receding half shifts toward the red. The net result is that all the star's spectral lines are broad and diffuse.

By measuring the breadth of the spectral lines, Bopp and Stencel found that FK Comae stars rotate incredibly fast — 100 km/sec. With most G and K type giant stars, rotation speeds of even 10 km/sec are rare — though on occasion, when a giant star is part of a binary system, it might rotate as fast as 50 km/sec. Despite their rapid rotation and spectral resemblance to RS Canum Venaticorum stars, FK Comae stars seem to be single.

Why? If they were binary systems, each member would alternately approach and recede from us as it orbited the common center of mass for the system. This would show up in the spectrum as a periodic doubling of all spectral lines: the orbital velocity would shift each star's spectrum toward either the red or blue. The effect would show up most clearly when the orbital plane of the two stars was in our line of sight, but it could also be detected

AstroNews

even if the system were tilted at a considerable angle. Since no doubling of the lines has been seen in any of the three FK Comae stars, they are probably single.

How did they get this way? It's possible they might have been rapid rotators all along, but astronomers, using the "spinning skater" analogy, have good physical arguments against this. If you take the present spin rate of these stars and calculate how much faster it would have been earlier in their evolution — back when they were smaller stars on the main sequence — the spin rate would be so great they couldn't have held together at all. Centrifugal force would have flung off great quantities of material from their equators.

Bopp and Stencel propose that FK Comae stars may once have been "contact binaries" — two stars so close together their atmospheres touch. The gravitational pull of each member in such a system elongates the other member and both end up egg-shaped. When one of the two stars evolves to leave the main sequence — expanding and becoming a giant — it engulfs the other.

In 1976 astronomer Ronald F. Webbink predicted that once either star in a contact binary system became a giant, the whole system should appear as a single star of type G, rotating about 100 km/sec, with a period of a few days.

And that, as Bopp and Stencel note, sounds just like FK Comae. *Ken Croswell.*

1 Billion Degree Plasma Discovered by Voyager 2

Space scientists, using data collected by Voyager 2 during its flyby of Saturn this past August, have found a place in the solar system containing the hottest gas yet observed. Temperatures in a region of space around Saturn range from 600 million to over 1 billion degrees Fahrenheit.

The hot gas is an enormous doughnut-shaped region, or *torus*, encircling Saturn at an altitude ranging from 273,000 kilometers above the planet's cloudtops to as high as 724,000 km. Its temperature is about 300 times hotter than the solar corona, and twice as hot as the Jupiter plasma cloud discovered by Voyager 1 in 1979. The spacecraft survived passage through this region because the density of the gas is very low — only about thirty particles per cubic foot. The dearth of particles could not heat the spacecraft to the point of harming it.

The Low Energy Charged Particle instrument, which made the observation, is designed to measure ions and electrons that move at speeds up to a few thousand miles per second in the magnetospheres of the planets and in the interplanetary medium. The instrument can distinguish hydrogen, helium, oxygen, sulfur, sodium. It also measures the direction in which these high speed particles are moving and the temperature of this particle population when the plasma

NRL Reports Evidence of Cometary Collision with Sun

Scientists at the Naval Research Laboratory report that on August 30, 1979, a comet collided with the Sun, scattering cometary debris in an immense halo that rose millions of miles above the solar surface. This event marks the first positive evidence of a celestial body colliding with the Sun, and is the first comet discovery by satellite instrumentation.

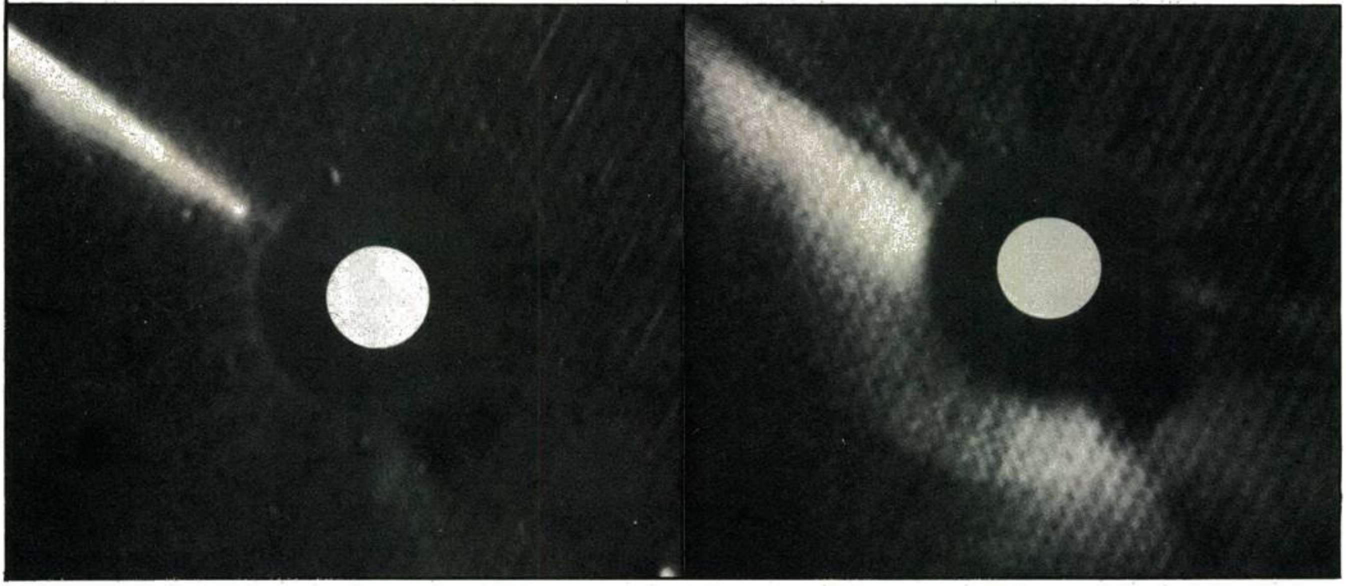
The SOLWIND experiment, which recorded the collision, contains a coronagraph that monitors activity in the Sun's outer corona. It provides a view of the corona similar to that seen from the ground during a total solar eclipse. The coronagraph has an "artificial moon," or occulting disk, which provides a continuous "solar eclipse." "Total eclipses observed from the Earth last no more than a few minutes," says Donald Michels, chief scientist on the NRL/SOLWIND project, "while SOLWIND has been able to observe the Sun's corona through these artificial eclipses night and day for nearly three years."

According to Michels, the comet passed through the instrument's field of view as it streaked on its collision course with the Sun. It quickly disintegrated upon impact in the Sun's blazing heat.

NRL researchers believe the new comet may have been one of a special group of comets in orbits that pass very close to the Sun. Dubbed "sun-grazers," these comets skim the solar surface in near-miss trajectories. About eight sungrazers have been sighted over the past three hundred years, but many more may have escaped detection because the Sun's glare makes them difficult to view from Earth. For example, the comet detected by SOLWIND was not sighted from the ground even though its tail was brighter than Venus.

NRL researchers are now checking with ground-based observatories for any telltale signs of the comet's entry into the Sun's atmosphere. Scientists estimate that the impact of this comet released energy of about 10^{30} ergs — about one thousand times that used in the U.S. during an entire year.

Left: The sun-grazing comet imaged by SOLWIND approaches the Sun at 640,000 mph. Right: A cometary dust cloud rises high above the solar surface more than 11 hours after the comet collided with the Sun. Naval Research Laboratory photos.



is very hot — tens of millions of degrees.

The region of space around Saturn occupied by the hot plasma torus centers around the orbits of Dione and Rhea, two of Saturn's icy moons, and extends farther away from the planet on the dayside than on the nightside.

Evidence for Close Binary Stars in Globular Cluster?

For some time, close binary stars have been suspected as a major influence in the evolution of globular clusters. But it is difficult to detect these binaries, because even the closest globulars lie far away. Both spectroscopic and radial velocity measurements have been unsuccessful.

Recently, however, three astronomers — Bruce Margon of the University of Washington, Ronald A. Downes of UCLA, and James E. Gunn of Caltech — have presented evidence for the presence of close binary star systems in globular clusters in *Astrophysical Journal Letters.* Their candidate is V101, a star that appears to be located in the globular cluster M-5, in the constellation Serpens. Their examination of its variability, color, and spectrum indicates V101 is a dwarf nova.

Astronomers think dwarf novae are close binary stars which flare up occasionally. The most famous member of this class is U Geminorum. In such systems we find two stars: a hot, dense blue dwarf and a large, red star. Material shed from the tenuous outermost layers of the large red star falls at intervals onto the surface of the dwarf star, where it becomes much hotter and abruptly flares up in brightness.

The astronomers are convinced that V101 is a member of the M-5 cluster and not just in our line of sight.

If V101 is, in fact, a member, scientists say this is the best evidence yet found that close binary stars exist in globular clusters. *Ken Croswell.*

Astronomers Measure 100,000°K White Dwarf

Astronomers have found a white dwarf in Ursa Major with a temperature of about 100,000°K — the hottest known star of this class. The star is 20 times as hot as the surface of the Sun but only the size of Earth. BE Ursae Majoris is 300 light-years from Earth.

The hottest previously known white dwarfs have temperatures of about 70,000°K. The find is important to scientists studying the evolution of stars because little is known about the white dwarf stage, which stars, including our Sun, pass through.

Measuring the white dwarf's temperature was especially difficult because an object of such intense heat emits most of its light in the ultraviolet region of the electromagnetic spectrum. Much of this light is absorbed by the Earth's atmosphere, so astronomers cannot accurately measure the star's luminosity. Therefore, they were unable to calculate its temperature with standard methods.

Instead, because they knew the white dwarf was a member of a close binary system, they calculated its temperature by the effect it had on the blue shift of its companion star.

Bruce Margon, Jonathan Katz, and Ronald Downes measured the temperature of the white dwarf BE Ursae Majoris using the 84-inch optical telescope at Kitt Peak.

Scientists Find Molecular Clouds at Edge of Galaxy

Astronomers have reported huge clouds at the outer edges of the Milky Way Galaxy that could form part of a previously unknown galactic spiral arm stretching for 30,000 light-years.

These clouds, called molecular clouds because they are made up of molecules such as hydrogen and carbon monoxide, are believed by astronomers to be the place where most stars are born.

Marc Kutner, an astrophysicist, and Kathryn Mead, a graduate student, made their observations using a 36-foot radio telescope of the National Radio Astronomy Observatory on Kitt Peak. The telescope is designed to work at radio wavelengths of a few millimeters and has been used to detect more interstellar molecules than any other telescope in the world.

Several of the newly discovered clouds are 200 light-years long and may be as massive as 100,000 Suns. They are similar to clouds already studied in the inner Galaxy. Also, although there is evidence that star formation takes place in both the inner and outer galactic clouds, the mixture of star types is different in both regions.

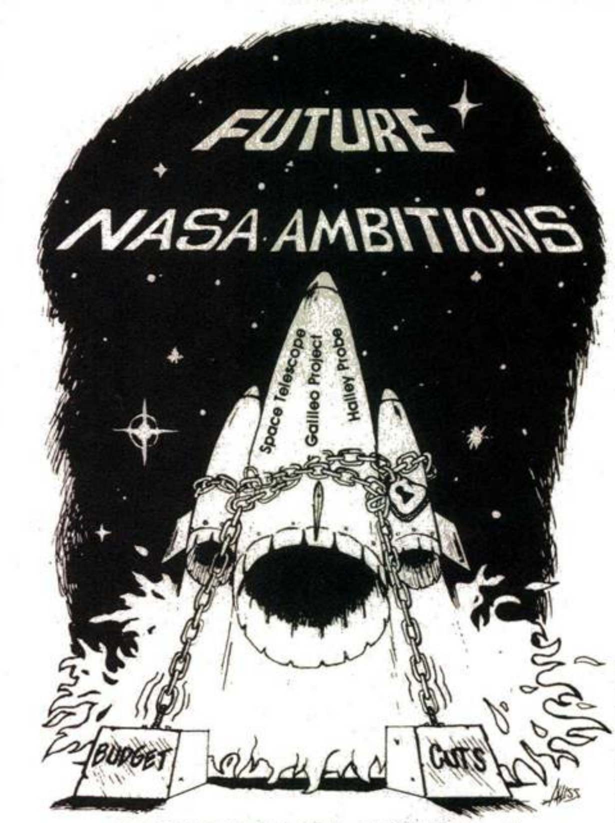
Before this discovery, most molecular clouds were thought to be confined to a band within the orbit of the Sun around the center of the Galaxy. The Sun is about 30,000 light-years from the galactic center. This new observation shows that the clouds extend out at least twice this distance from the galactic center.

"There may be as many clouds outside the Sun's orbit as inside it," Kutner said. "This indicates that stars are being created in our Galaxy in a region twice as large as previously thought."

The clouds in the outer Galaxy had not been seen before because previous observations were concentrated in the flat extensions of the disk or plane of the Milky Way. However, scientists have known for several years that in the outer part the Galaxy is not flat, but warped or bent somewhat like the brim of a hat. The newly discovered clouds follow this warp.

The Saskatoon Center of the Royal Astronomical Society of Canada (RASC) will host the annual RASC General Assembly meeting on Thursday, May 20, 1982. For more information contact: Saskatoon Centre, R.A.S.C., P.O. Box #317 Sub 6, Saskatoon, Saskatchewan S7N 0W0.

SHUTTLE LAUNCH
January 1, 1982



"T-MINUS 1982 AND HOLDING. . ."

Cartoon by Gregg R. Alliss

ASTRONOMY REVIEWS

The Milky Way
Bart and Priscilla Bok
356 pages, hardbound, $20.00
Harvard University Press (1981)

Since 1941, the general reader's definitive book on our home Galaxy has been Bart and Priscilla Bok's *The Milky Way*. While it maintains the superior quality and readability of the preceding four versions, this fifth edition delivers an even grander overview of the silvery band that arches across the night skies of Earth.

The Milky Way is an up-to-date and thoughtful synthesis of fact and theory pertinent to our Galaxy. The writing is sound and enthusiastic — though somewhat technical — and most ASTRONOMY readers will enjoy it. The book is also printed and bound well, something that's all too rare these days.

Since many of us enjoy astronomy visually and photographically, the numerous crisp black-and-white photographs are a welcome part of the book. As another plus, Bok has avoided using the standard shots that many readers have already seen.

Against the background of our Galaxy's massive starry arms turning about the central nucleus, the author poses some provocative questions. What are the chances of stellar collisions? How likely is it that some wandering star will loom menacingly on the solar system's horizon, profoundly affecting the Earth? What lies hidden at the very heart of our Galaxy?

Our model of the Galaxy has undergone numerous alterations and corrections over the years. Conjecture, puzzlement and superstition have given way as computer modeling, new observations, and calculated extrapolation create a more precise concept of what our Galaxy is. Under the probing gaze of radio, infrared, gamma, and X-ray observations, a veritable cornucopia of hypotheses has poured forth, markedly altering our perception of the Milky Way.

These non-optical observations have allowed us to explore farther and see more critically into the dark reaches of our Galaxy. As Bok points out, they have been crucial because only one part in 1,000 billion of the total radiation emitted by the center of our Galaxy is visible in the optical region of the spectrum.

Bok also challenges his readers to expand their thinking. About midway through the book, he introduces the *gigayear*, a unit of time equal to one billion years: our Sun is about five gigayears old. A "cosmic year" — one revolution of our Sun and its retinue of planets around the galactic nucleus — is equivalent to 240 million Earth years. Accordingly, our Sun has contributed its rather inconsiderable gleam to the galactic glow for just 20 cosmic years.

To gaze into our Galaxy is, of course, to look back in time. With present day Earth-bound telescopes, we see the most distant objects our telescopes can resolve as they were eight to 10 billion years ago. But, Bok relates with relish, this limit will be greatly exceeded when the Earth-orbiting Space Telescope goes into operation and reaches back 20 to 25 billion years.

Bok's prose paints a striking starscape of our stellar city wheeling silently in the void of intergalactic space. He focuses on previously indistinct galactic vistas and makes it easy for his reader to visualize the mysteries of our Galaxy. His text includes stellar dynamics, star clusters, nebulae, data gathering, and galactic changes.

All of us who have looked up under a dark sky at the starry sweep of the Milky Way will feel a sense of camaraderie and awe as Bok leads us in this armchair exploration of the Milky Way. In a masterpiece of understatement, he says, "It is a good thing to describe the Galaxy in all its majesty and to study the properties of its many components." His excellent book is compelling evidence of this. *Gail O. Clark.*

Cosmology
Edward R. Harrison
430 pages, hardcover, $24.95
Cambridge University Press (1981)

Harrison's book starts at an elementary level and assumes the reader has no teacher to answer questions. Accordingly, the author is scrupulously careful to explain things as fully as possible and gives some very good "think-it-through-for-yourself" exercises.

Earth Watch
Charles Sheffield
160 pages, hardcover, $24.95
Macmillan (1981)

Satellite imagery of the Earth from space has become almost commonplace. Despite that, *Earth Watch* manages to be arrestingly different. It shows 70 color photographs taken by Landsats 1, 2, and 3 — most of them previously unpublished — arranged in eight topics including Signs of Man; Bays, Capes, and Harbors; Cities and Deserts. Each photograph is accompanied by a commentary.

Aristarchus of Samos; the Ancient Copernicus
Thomas Heath
425 pages, paperback, $7.00
Dover Publications (1981)

As the subtitle tips you off, Aristarchus believed in a heliocentric universe. He was nearly alone among Greek philosophers in this belief — in fact, his arguments were the only defense of the theory until Copernicus published *De Revolutionibus* in 1543.

This edition reprints a work first published in 1913 by Oxford University Press. The first part of it contains a history of Greek astronomy up to the time of Aristarchus, who lived *ca.* 310 to 230 B.C., and the second is a translation of his work on the sizes and distances of the Sun and Moon. The Greek original is on the lefthand pages, the English translation on the right. Heath provides full introductions to both parts, plus ample notes.

Comets
Christopher Owen Irwin
42 pages, hardcover, $25.00
Mosaic Press (1981)
[Order from the publisher: 358 Oliver Rd., Cincinnati, OH 45215]

What makes a 42-page book worth $25? To start with, it's handbound in leather with marbled endpapers, and has a gilded backstrip, edges, and front cover. It also has full-page pen and ink illustrations.

But that's not why it costs $25. The real reason is that the book measures just under an inch high by ¾" wide by 3/16" thick!

While the slight text — and what do you expect in 42 minuscule pages? — will tell you what comets are, where they come from, and what people have thought and feared about them, don't expect a lot of substantial information.

This is a fine item for a book collector who: a) loves little volumes, b) likes astronomy, and c) is willing to indulge in a bit of whimsy.

Origin of Life
Yecheskel Wolman, ed.
613 pages, hardcover, $73.50
D. Reidel Publishing (1981)

The question of how life began on Earth remains unanswered. *Origin of Life* reprints the technical papers given at a conference in Jerusalem sponsored by the International Society for the Study of the Origins of Life.

Physical Processes in Red Giants
I. Iben and A. Renzini, eds.
488 pages, hardcover, $66
D. Reidel Publishing (1981)

The red-giant phase of a star's lifetime is the beginning of the end: a period when it simultaneously grows larger and maintains the same surface temperature. The astrophysics of what happens inside such a star was the topic of an international conference held in September 1980. The book is a collection of the papers presented.

Discovering Astronomy
W. H. Jefferys and R. R. Robbins
466 pages, hardcover, $25.95
John Wiley & Sons (1981)

Discovering Astronomy is a textbook for astronomy courses aimed at non-science students. It emphasizes the experimental and observational aspects and includes a packet of punch-out-and-assemble cardboard instruments.

The Case for Space Colonization — Now!!
Oscar Falconi
22 pages, paperback, $1.25
Research Publications (1981)
[order from publisher: Box 1113, Sunnyvale, CA 94088]

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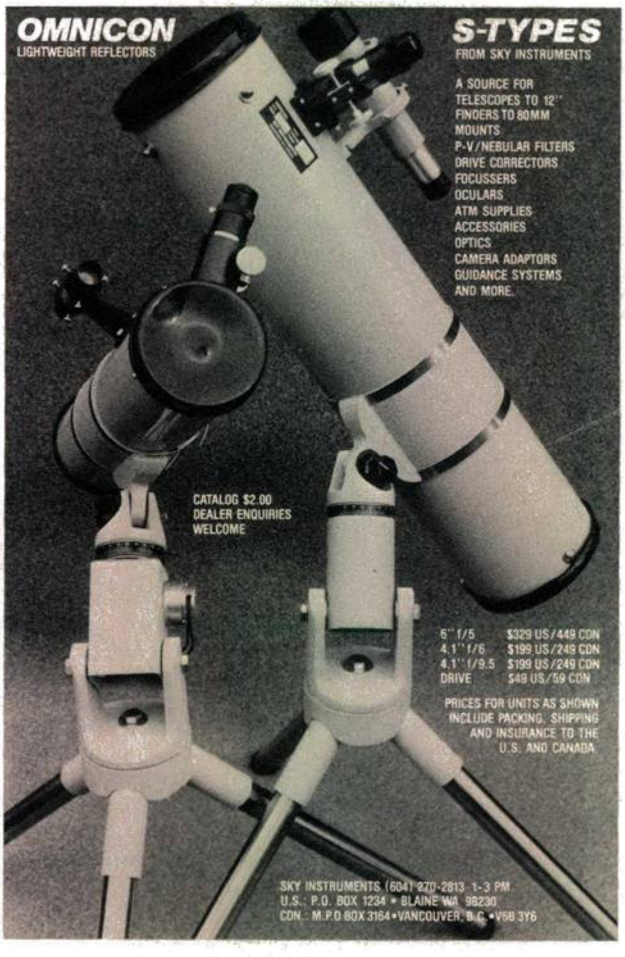
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Science: Good, Bad, and Bogus
Martin Gardner
408 pages, hardcover, $18.95
Prometheus Books (1981)

The good science in these reprinted essays is revealed by a long and detailed look at the bad and the bogus. Since few scientists are willing to wade into the morass of popular superstition and pseudo-science, Gardner's book (a sequel to his *Fads and Fallacies in the Name of Science*) is a wonderful resource for those who wish to debunk the proposals of crazies and crackpots.

The Development of Astronomical Thought
Patrick Moore
108 pages, hardcover, £4.95
Ian Henry Publications (1981)

Despite the book's 1981 publication date, the author's preface is dated August 1979. In it, he states that the book "is, I hope, now complete to 1972." So much for the book's currency!

The text provides a history of how man's changing perception of the universe has influenced his thoughts on other matters. The emphasis is on the period since the Renaissance.

Fundamental Problems in the Theory of Stellar Evolution
D. Sugimoto, D. Q. Lamb, and D. N. Schramm, eds.
347 pages, paperback, $21
D. Reidel Publishing (1981)

Although astronomers seem to have a clearly delineated picture of stellar evolution, observational data and computer modeling show that many complexities are unresolved. This book records the proceedings of an I.A.U. symposium held in July 1980.

Origin of Cosmic Rays
G. Setti, G. Spada, and A. W. Wolfendale, eds.
409 pages, paperback, $23.50
D. Reidel Publishing (1981)

Though they were discovered in 1912, we still can't fully explain the origins of cosmic rays. These high-energy particles come from outside the solar system and are thought to be produced by supernovae. The International Astronomical Union sponsored a symposium on the subject in June 1980. *Origin of Cosmic Rays* is a collection of the conference papers.

Galactic Astronomy
Dmitri Mihalas and James Binney
597 pages, hardcover, $29.95
W. H. Freeman & Co. (1981)

When the first edition of this book was published in 1967, it contained 256 pages. Since then, the subject has grown so complex and detailed that the second edition will appear in two separate volumes. This is the first, and it is subtitled *Structure and Kinematics*. The projected second volume will deal with the dynamics of individual galaxies and clusters of galaxies. The level of writing is solidly mathematical.

X-ray Astronomy with the Einstein Satellite
Riccardo Giacconi, ed.
330 pages, hardcover, $44.50
D. Reidel Publishing (1981)

When the Einstein satellite (HEAO-2) was launched in 1978, X-ray astronomers began to observe the sky with a high-resolution imager. A conference was held in January 1980 at the Harvard/Smithsonian Center for Astrophysics to discuss the rather predictable wave of discoveries that resulted. This book records the papers presented there.

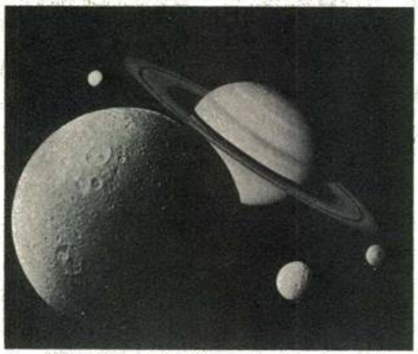
Annual Review of Astronomy and Astrophysics, Vol. 19
Geoffrey Burbidge, ed.
479 pages, hardcover, $20
Annual Reviews (1981)

The 1981 volume contains 14 review articles on topics including solar coronal heating mechanisms, compact radio sources, masers, and the extragalactic distance scale. The authors of the reviews assume a professional reader, but the first article in the book, traditionally a personal memoir by a noted astronomer (in this case, Jan Oort), is more general.

Ice
Fred Hoyle
191 pages, hardcover, $12.95
Continuum (1981)

Subtitled "the ultimate human catastrophe," *Ice* offers Hoyle's explanation for ice ages. Indignantly rejecting the currently favored Milankovitch model which calls for long-term changes in the Earth's orbit, Hoyle advocates a chain of events started by meteor impact. Though it's not likely to be accepted by geologists and geophysicists, most of Hoyle's ideas here are interesting — even where he seems to say that another glaciation would be good for us as a species.

Voyager Visions



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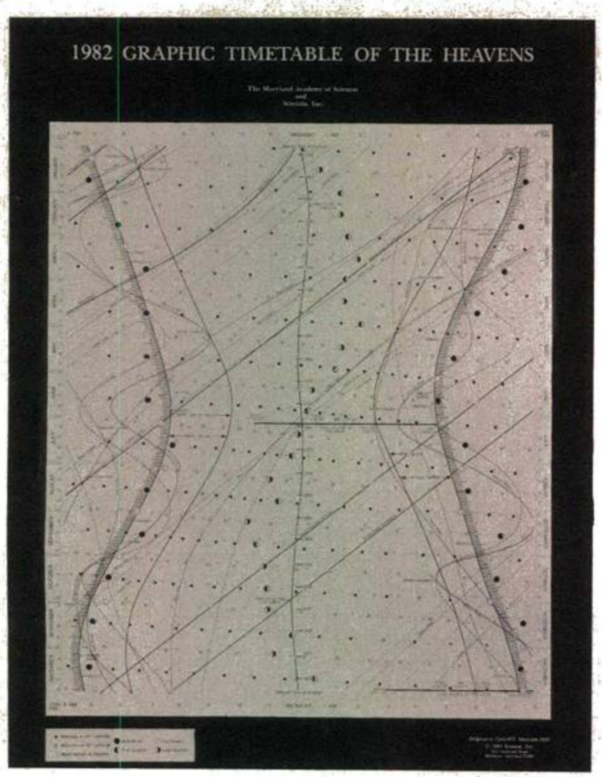

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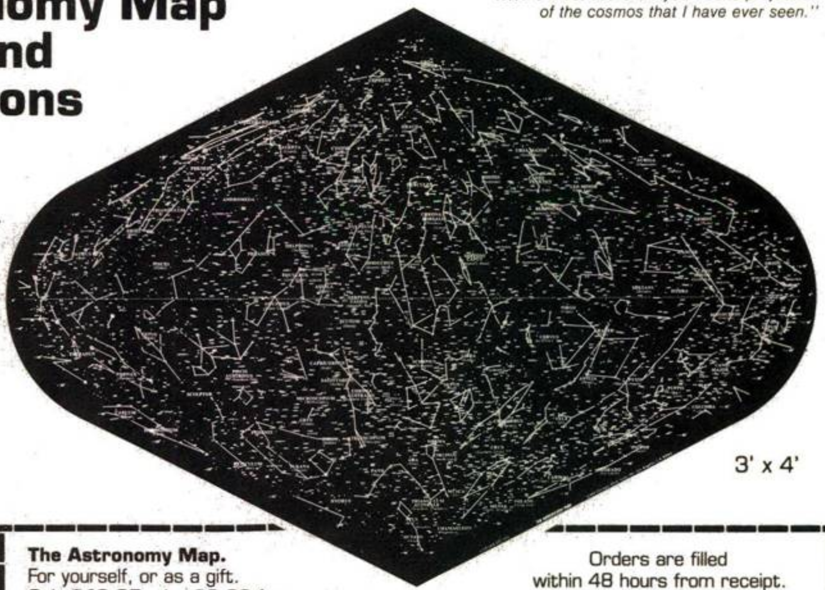

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July 1981
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Celestron International	42, 60-61, 96
Coast Navigation	81
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East African Travel Cons.	80
E&W Optical	80
Edmund Scientific	83
Evaporated Metal Films	71
Ganymede	71
Hansen Planetarium	68
Hoosier	80
L-5 Society	70
Lumicon	79
MacMillan Pub.	85
Meade Instruments	2-3,48-49
Optica b/c	82
Optron Systems	70
Orion Telescope Ctr	23
Questar Corp.	25
Sky Instruments	67
Sky Log	79
Sky Research	81
Space Graphics	71
Spherical Concepts	79
Star-Liner Co.	82
Star Tracker	27
Starry Messenger	80
Super-T	68
Tele Vue Optics	27
Thayer Instruments	81
Tomlin Ent.	71
Tuthill, Roger	56-57
Viking Fund	94
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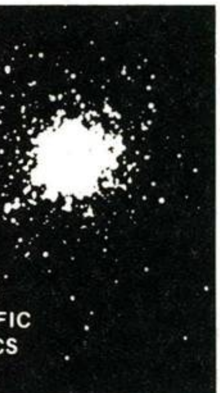
ANNOUNCEMENT — Mansfield and Sutton Astronomical Society meet at their own 'Sherwood Observatory', Coxmoor Road, Sutton-in-Ashfield, Nottinghamshire, England, on the last Monday of every month. 24-inch Nasmyth telescope under construction. Contact Graham W. SHEPHERD, 5, Priory Street, Old Lenton, NOTTINGHAM, England.

ANNOUNCEMENT — North Eastern Astronomical Society newly formed society, members wanted. We will have meets and star parties. More information available. Contact N.E.A.S., Box 862, N. Falmouth, MA 02556-0862.

ANNOUNCEMENT — Join the Amateur Astronomers Association, New York's largest group of its kind. We sponsor an educational program, lectures, public observing sessions, field trips, and more. Contact Amateur Astronomers Association, 1010 Park Ave., New York, NY 10028.



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UNDERGRADUATES — astronomy, physics wishing exchange ideas, projects, experimental results, articles. We're students planning non-profit publication. Marc Murison, Astronomy Dept., San Diego State University, San Diego, Calif. 92182 or Jerel Whittingham, Astronomy & Physics Dept., University College, Gower St., London.

ANNOUNCEMENT — STOLEN: Alvan Clark 8¼" full aperture objective in brass cell from Cincinnati Astronomical Society's telescope. Reward for informationleading to recovery. R. Kindred, 5884 Whipporwill Hollow, Milford, Ohio, 45140.

ANNOUNCEMENT — The Campaign for Space Political Action Committee is the political arm of the space constituency. Help us take the pro-space message to the policy makers in Washington. Contact The Campaign for Space, P.O. Box 1526, Bainbridge, GA 31717.

ANNOUNCEMENT — The Great Lakes Astronomy Club is forming. Anyone in this area is welcome to join. Contact: The Great Lakes Astronomy Club, 810 North East 5th Street, Marion, WI 54950, c/o Brian Stuhr.

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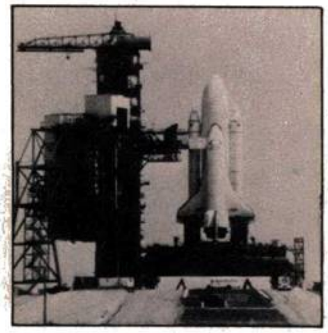

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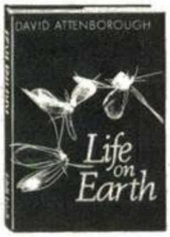
Q: What common creature is a direct descendant of the dinosaurs?

A: There may be one perched on your windowsill right now—the *bird*. Not only are birds direct descendants of the dinosaurs, but some biologists think they're even eligible for the title "living dinosaurs." (See *Extinction*)

Q: What fish goes fishing complete with line and bait?

A: It's called an anglerfish. It looks like a rock, and thus camouflages itself on the ocean bottom. Coming out of its mouth is a thin, wiggly structure that resembles a piece of string. At the end of the "string" is another structure that looks exactly like a tiny fish—an exquisitely accurate fake complete with eye-like spots of pigment, fins and tail. When an unsuspecting fish tries to snare the decoy, the anglerfish makes a quick meal of the visitor. (See *The Panda's Thumb*)



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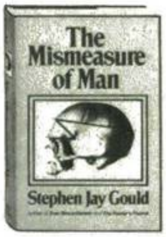

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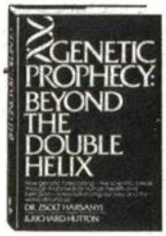

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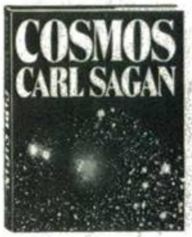

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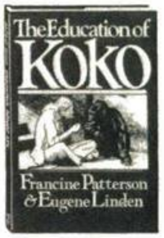

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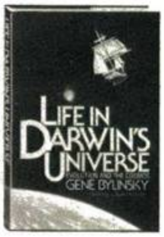

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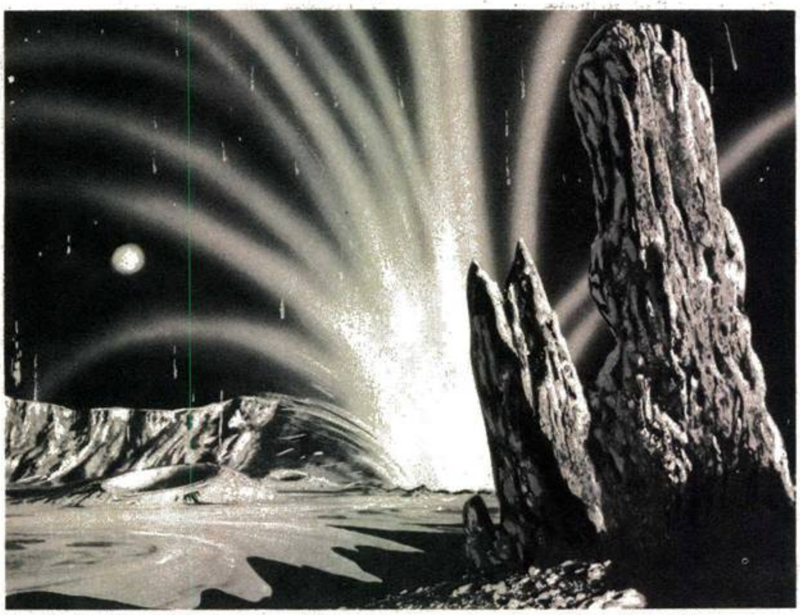

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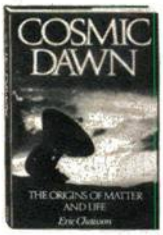

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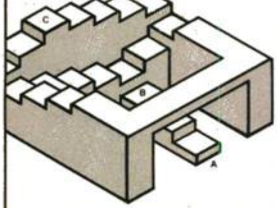

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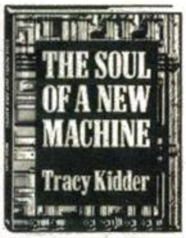

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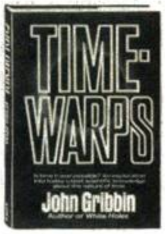

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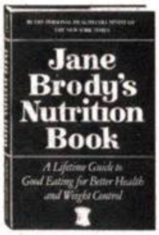
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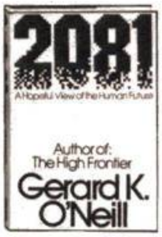
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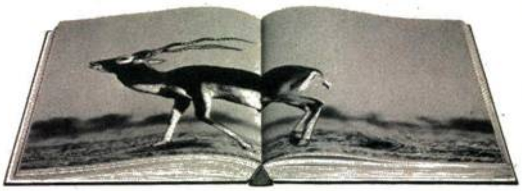

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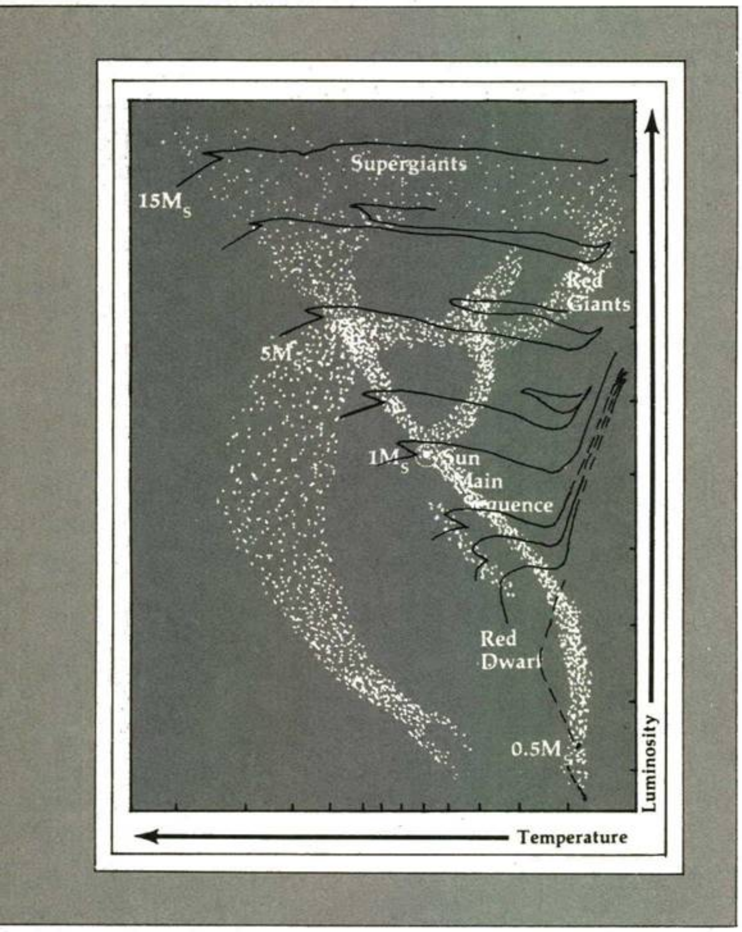
High Winds Beyond This Point

Although astronomers once believed the Sun lost mass only through a well understood thermal wind mechanism, observations now suggest that the Sun — and many other stars — drive away mass via much more complex mechanisms.

by Dermott Mullan



Astronomers use the Hertzsprung-Russell diagram to classify stars by temperature and luminosity. The diagram has helped us learn how stars evolve and die. The overprint is a set of evolutionary tracks that shows the direction stars in the range of 15 to 0.5 solar masses take as they age. Reproduced with permission of I. Iben from the Annual Review of *Astronomy and Astrophysics*, Vol. 5, © 1967 by Annual Reviews Inc.

Children's books sometimes show pictures consisting of random jumbles of red, green, and blue dots. The picture makes no sense unless you look at it through a colored filter — a piece of red glass, for example. The filter blocks the light from the green and blue dots, and lets the red stand out in a recognizable pattern.

Astronomers, too, have a "dot picture" that helps them obtain a quick overview of certain stellar properties. In this astronomical diagram, a star is symbolized by a dot placed in a location determined by the star's size and surface temperature. Stars on the right side of the diagram are cool, and appear reddish, while those on the left are white hot. Small stars, like the Sun, are called dwarfs, while stars with 10 or 100 times the Sun's diameter are called giants. This star-dot table is the *Hertzsprung-Russell* diagram, named for the Danish and American astronomers who formulated it early this century.

As stars were plotted on the Hertzsprung-Russell diagram, astronomers noted that more dots appeared in certain regions of the diagram than in others. For example, many of the dwarf stars clustered along a sequence stretching from upper left to lower right. To clarify the dot distribution, astronomers developed various filters. The most important filter could not be looked through — it was computer generated and consisted of a series of lines that trace the changes stars undergo as they age. There was a single line for each star's mass. According to the computer findings, a star with a mass equal to the Sun's spent most of its lifetime at a position on the Hertzsprung-Russell diagram close to the point on which the Sun lies. Scientists determined that the Sun will remain close to that point as long as there is hydrogen available to fuel its fusion reaction. When the hydrogen is expended, according to the computer, the Sun will begin to change physically. This will shift its location on the diagram toward the upper right.

The succession of points representing a star's changes is called its *evolutionary track*. Stars with less mass than the Sun have evolutionary tracks that start in the lower right corner, among the red dwarfs, and move almost vertically toward the red giants. Stars with masses greater than the Sun start as hotter dwarfs, and then evolve horizontally to reach the giant region.

When astronomers placed this computer filter over the "star-dots," a pattern emerged: the major clumping of dwarf stars was just where the computer predicted it would be — as long as the stars had hydrogen to burn. Also, the distribution of stars in the giant region closely followed the proposed evolutionary tracks.

This clarification of the jumble of "star-dots" in the H-R diagram was a major milestone in astronomy during the 1950s. The computer "filter" had done its job well, at least in the interpretation of current observations. However, the question remains: Are there any other "pictures" hidden in the star-dots that the initial computer filter missed? After all, it would be a fantastic stroke of luck if the very first filter revealed all of the information contained in the dots. Today new filters are finding new patterns that will undoubtedly stimulate new research on stellar atmospheres.

The first hint that the original computer filter was not complete appeared in the 1960s, when spacecraft discovered that the space around Earth contained a flow of material away from the Sun. This material is a very tenuous gas streaming by at speeds exceeding the strongest winds recorded in terrestrial hurricanes or tornados. At first, scientists thought the high speed of this escaping solar material was generated by forces similar to those that cause terrestrial winds — differences in pressure. Astronomers concluded that there was a region of high pressure in the Sun's atmosphere and a region of low pressure in the space between the stars — far beyond Earth's orbit. Earth lies between these pressure extremes, and is immersed in the wind that blows from the high to the low pressure areas. This flow was called the *solar wind*, and its discovery posed an important problem for astronomers who computed evolutionary tracks. After all, each track was computed on the assumption that the mass of a star remained constant, and yet the spacecraft which detected the solar wind proved that the nearest star, our own Sun, continuously gives off a stream of material. Astronomers concluded that the solar mass is not constant, but decreases steadily.

The good news for astronomers and everyone else on Earth is that the rate at which the solar wind carries away mass is small when we consider the total mass of the Sun. At its present rate, even after ten billion years the Sun will lose no more than 1% of its mass. For stars like the Sun we can assume that the mass stays constant regardless of this continuous loss of material. Of course if the Sun ever goes through a period of extreme mass loss, then the evolutionary tracks will have to be modified. The newest filters suggest that mass loss becomes rapid for stars with masses similar to the Sun's once the stars enter a certain part of the H-R diagram.

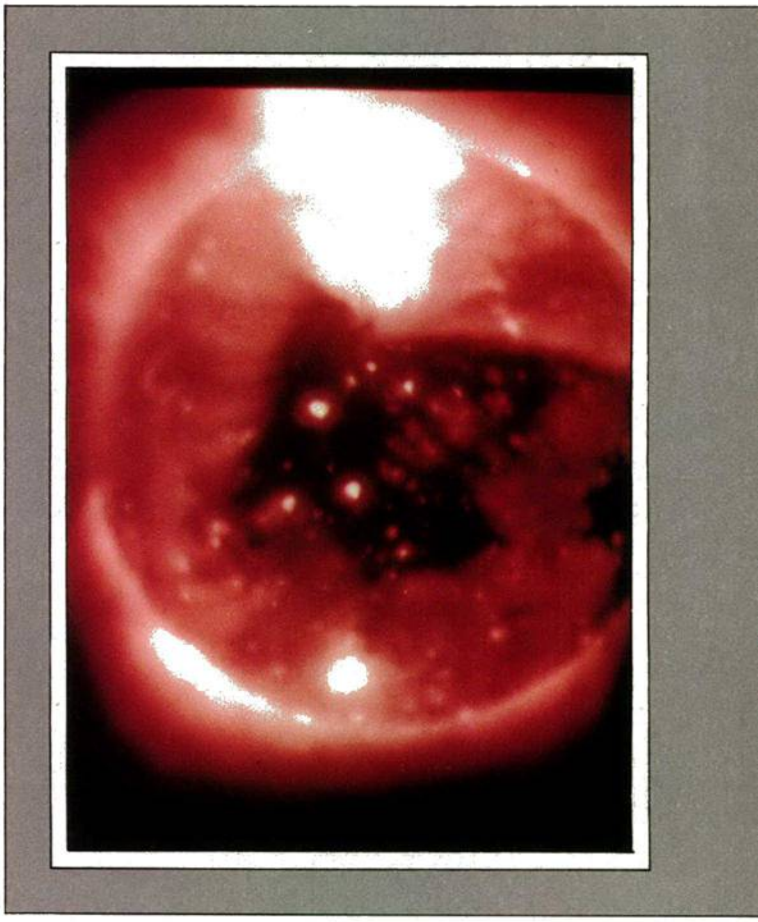
Before we consider the results drawn from the newest filters, we should consider the key element in the creation of the solar wind — the high pressure region in the Sun's atmosphere. If solar winds are driven by a mechanism similar to the force that moves their earthly counterparts, then the solar atmosphere must be very hot — one million degrees or more.

The solar surface visible to us contains gases of only a few thousand degrees Kelvin. If the Sun's atmosphere was only this hot, then there could be no pressure excess between its outer atmosphere and the space between the stars — and consequently no reason for the wind to blow away from the Sun into space. But the Sun's outer atmosphere does contain gases that are hotter than one million degrees Kelvin; they form the corona. Today, astronomers don't know for certain how the gas in the corona is heated to these extremely high temperatures.

The fact that the Sun always has some kind of corona has been established by eclipse observations and by special telescopes called coronagraphs. Therefore, whatever heats the corona is always available to some extent in the Sun's atmosphere. X-ray photos from Skylab show that even higher temperatures are produced for short intervals in localized regions of the Sun. These very hot regions are called flares. Temperatures in flares can reach 100 million degrees — and hotter. From ground-based observations, astronomers have learned that flares occur in regions where magnetic fields are unusually strong and distorted. Distortions of magnetic fields seem to be related to the heating of gas in the Sun.

Can the normal heating of the corona also be attributed to a magnetic process similar to that in flares? The answer might be yes. The corona, apart from flares, shines brightest in the X-ray portion of the spectrum precisely where magnetic fields with a particular type of distortion are present. The distortion that favors bright X-rays is strong curvature. If a magnetic field emerges from the Sun's surface, loops up into the atmosphere for a short distance, and then curves back downward into the Sun to form an arch-like structure, the material on the arch has a good chance of showing brightly in an X-ray photograph. Since both "feet" of the arch are resting in the Sun, the material that enters the arch at one end is channeled, via the magnetic field, back into the Sun at the other end of the arch. Since this arch is "closed," the material in it remains trapped. Closed loops can trap hot, dense gas for several days in the solar atmosphere, so these loops are relatively stable elements in the corona. In fact, since the loops are the only outstanding regions emitting X-rays, they are often considered to be the corona itself.

The corona displays a completely different set of characteristics in regions where the magnetic field is not distorted. Here, magnetic field lines emerge from the Sun's surface and extend upward so far into space that by the time they bend over to return to the Sun, they can no longer do so. The solar wind blows so strongly at the peak of the arch that the Sun's magnetic field cannot return to the solar surface. These lines of the Sun's magnetic field never return, and matter flows upward along them, eventually escaping from the Sun. These regions are observed most frequently near the poles of the Sun. Whatever the mechanism that heats the gas on closed field lines, it obviously does not work as well on open field lines. The gas in these is also heated to one million degrees, but it is not as dense as that in the closed loops.



The solar surface appears like this in the X-ray portion of the spectrum. The light areas are X-ray bright points and flare regions. The dark blotches are coronal holes. Though the holes are extremely hot, they are cooler than the bright points, so they appear empty in this photograph. Photo courtesy John M. Davis, Solar Physics Group, American Science and Engineering, Inc.

Because of this disparity in density, the radiation observed at the poles of the Sun is less brilliant. On an X-ray photograph, closed loops stand out as bright features, while open field regions look like dark holes that someone forgot to fill in. These *coronal holes* which appear almost empty in X-ray pictures, contain some gas at pressures still quite high compared to the gas pressures in space. This pressure difference might account for winds that blow away from the Sun. Matter flowing through the open coronal holes escapes into space, and therefore, the coronal holes could hold the key to how the Sun's mass is lost. The data returned by Skylab and other satellites launched during the 1970s helped astronomers understand this process: they indicated that the Sun does not lose matter at the same rate from all parts of its surface. Surprises still emerge from Skylab photographs, as investigators re-examine the data and ask new questions. One of these surprises will be mentioned later.

We can now turn from the Sun to other stars, and consider the results that emerged from the H-R diagram when the dots were viewed through *corona* and *mass-loss* filters.

A corona filter shows us which stars have gas in their atmospheres at temperatures approaching one million degrees. A mass-loss filter lets us pick out the stars exhibiting rapid mass loss. These filters became available in 1978 when the International Ultraviolet Explorer (IUE) and the second High Energy Astronomical Observatory (HEAO-B, Einstein) were launched. The IUE carries a telescope that collects light from a star and obtains a spectrum in the ultraviolet between 1000 and 3000 Angstroms. The Einstein satellite obtains pictures of stars that strongly radiate X-rays.

The IUE satellite is not particularly sensitive to gas at temperatures high enough to be in the corona. The hottest gas that IUE can sense is less than one million degrees. Although it is difficult to directly detect coronal gas with the IUE, astronomers infer that if the satellite's instruments measure a gas at 300,000 K, the star might also harbor gases at temperatures approaching one million degrees. IUE carried, in effect, an "almost coronal" filter. When the star-dots were viewed through it, astronomers saw a new picture — only stars in a certain part of the H-R diagram passed through. Stars in the upper right corner of the diagram were blacked out. When the true corona filter of the Einstein satellite was placed on top of the star-dots, the picture seen through the IUE filter stood out even more sharply. The stars in the red giant region were blacked out. Dwarf stars and the hotter giants shine through the corona filter, but it is like entering a dark hole when a certain boundary of the H-R diagram is crossed. X-rays from gas at one million degrees no longer appear. The boundary between corona stars and non-corona stars is not infinitely sharp, but it is abrupt enough to stand out as a prominent feature in the H-R diagram.

The mass-loss filter provided by the IUE examines the shapes of spectral lines in great detail. In the spectrum of a star that is losing mass, the outflow of gas distorts the shape of the spectral lines in a predictable way. The IUE satellite made it possible to detect these distortions in a large number of stars. When this mass-loss filter was used, a striking feature emerged — most of the star-dots in the H-R diagram were blacked out (including the Sun, which loses mass very slowly), but one group of cool stars stood out clearly as objects where rapid mass loss is in progress — the same stars that showed no coronal gas.

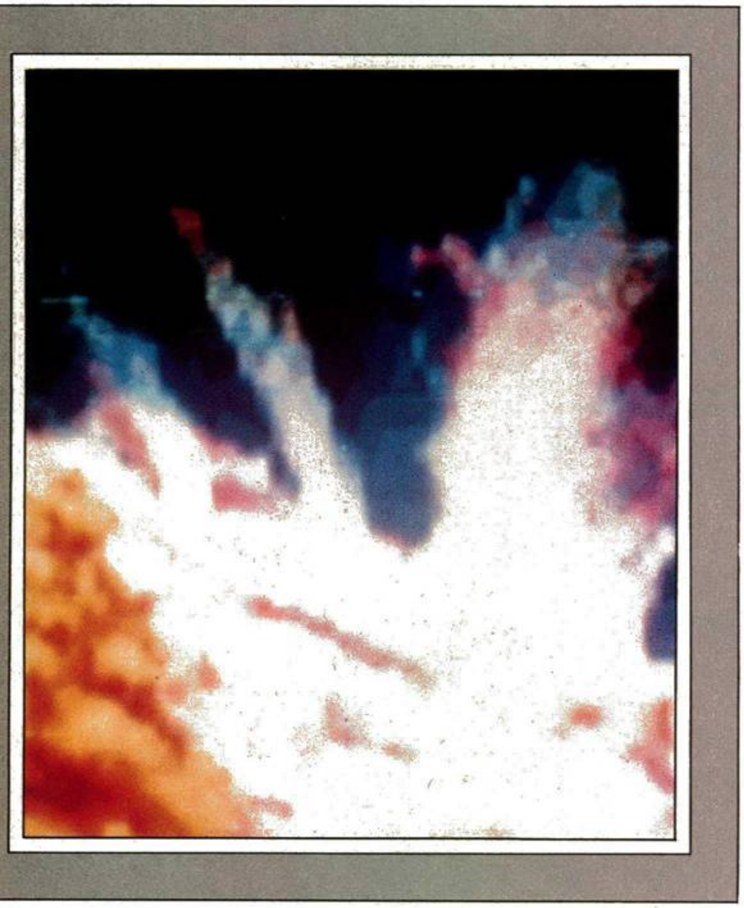
As before, a pattern emerged in the H-R diagram. Although astronomers argue about how sharp the boundary is, it is hardly possible to argue away the existence of a boundary altogether — especially in view of the coincidence between the data revealed by the mass-loss filter and the corona filter. Two satellites — designed to observe very different portions of the radiation coming from stellar spectra — had independently converged on a new boundary in the H-R diagram.

This sequence of photos (left to right) shows gaseous material from the surface of the Sun forming a closed loop. Continuing pressure will cause it to thrust out from the Sun in a violent manner and become an open loop through which solar material is lost. Photo courtesy E.J. Schmahl, Harvard College Observatory.

Continuing observations with the IUE's mass-loss filter and with a similar filter on an Earth-based telescope, have shown that something else changes across the newly found boundary — variations in the mass loss process. When mass loss is rapid, there are large fluctuations in the mass loss process. In stars where the mass loss is slower — the Sun, for example — the rate of loss is sufficiently constant that variations in the mass from day to day or from year to year have not been detected in the spectral data.

This new picture took astronomers by surprise and contained the makings of a challenging mystery. After all, the time-honored explanation of mass loss from the Sun is that the high pressure of hot gas in the Sun's atmosphere drives a wind. If this were also true for other stars, the heaviest winds would be driven by the highest pressures.

Observations indicate an opposite process. The stars with heaviest mass loss — at least among the cool stars — seem to have lower pressures in the atmospheres, so low in fact that the coronal pressures cannot be detected. This poses a potentially serious challenge to our understanding of how cool giant stars lose mass so rapidly. Another process, other than gas pressure, must be invoked to explain mass loss in these giants. Magnetic effects are a prime suspect.



We find our first clue by recalling the process on the Sun — where mass loss is strongest from regions where the evidence for coronal gas is weakest. Could the cool giants have atmospheres similar to coronal holes, with open field lines and great mass loss, but with little X-ray emission? Might the hotter giants and dwarfs have mostly closed magnetic loops, with heavy X-ray emission and little mass loss? This is an interesting speculation, but it really does not answer the question. Why should magnetic fields be mostly open in cool giants and mostly closed in hotter giants and dwarfs? This question in turn leads to a more fundamental one. Why are some magnetic field lines closed and others open?

Admittedly, when the question is posed like that, it is somewhat dishonest because there is no such thing as a truly open field line. The laws of physics say that all magnetic field lines remain closed. When a star creates a new magnetic field, that field appears at the star's surface as a closed loop, with both feet-points on the surface. A more honest question to ask therefore might be: Why do some magnetic field loops remain close to the surface of the star (thereby trapping gas and preventing mass loss), while other loops become distended upward to great distances from the surface of the star?

To answer this question, let's consider a phenomenon that has been studied for more than a century now — the solar flare. A flare is an explosion in the Sun's atmosphere that liberates a large amount of energy in a short time. Its energy release is so great that some gas in the immediate vicinity of the explosion is heated to more than 100 million degrees. However, when flares are large enough, and when they release their energy quickly, they can also eject a large quantity of matter from the Sun — as much from a small area as the rest of the Sun ejects in a 24-hour period. When we consider that the area of a flare amounts to no more than one percent of the surface of the Sun, it becomes clear that flares can be a conduit for very rapid mass loss.

This is even more remarkable since flares usually occur in regions of closed magnetic fields. Flares never occur in coronal holes — the prime example of open field regions. In the course of the flare, the magnetic field is somehow changed from closed to open and, as a result, matter can then be ejected. We don't know what causes the change from closed to open field lines. Scientists have proposed various ideas, including processes that mix originally closed lines with originally open lines. This mixing is followed by a special kind of field-line merging called *reconnecting*. The source of energy release in a solar flare is probably related to the reconnection of magnetic field lines — an efficient way to release energy stored in the magnetic field.

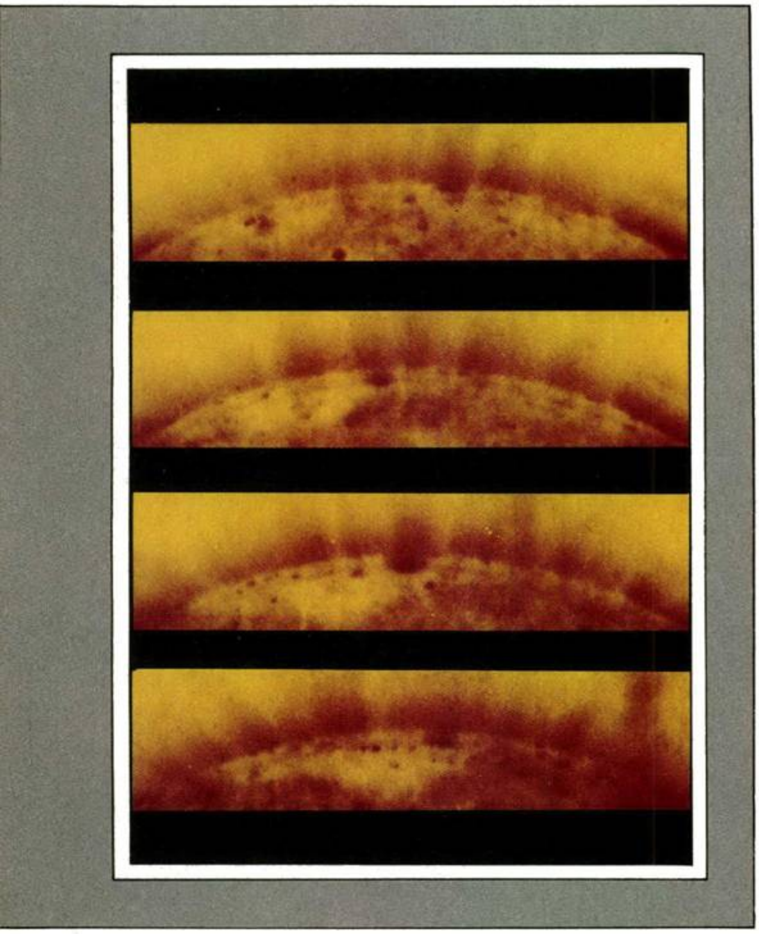
If reconnection is the process in the Sun's atmosphere that paves the way for field lines to open and allows the ejection of matter, could the energy released by the process aid the ejection? And might reconnection actually drive the mass loss process?.

This brings us back to the cool giants and their strong mass loss, and the postulate that the mass loss cannot be driven by a high pressure wind. Could the mass loss in these stars be driven by the energy released when magnetic fields change from closed to open? Until recently, we had no way to answer this question, but new analyses of photographs taken from Skylab in 1973-74 have produced evidence that offers intriguing possibilities.

The Skylab data concern X-ray photographs of coronal holes. Remember, these holes are *almost* completely dark in the photographs, but they do contain isolated patches of bright X-ray emission so small they are called *X-ray bright points*. The coronal holes around the poles of the Sun may each contain five or ten X-ray bright points at any one time. Usually they last no longer than a day, then fade away as others take their place elsewhere. Careful analysis of some bright points near the poles shows that streams of matter seem to flow upward and out of the bright points. The streams flow along features that have been observed for many years in photographs of the corona obtained during eclipses — these features are called *polar plumes*, rays of denser matter jutting out of the Sun's polar regions. There seems to be enough matter streaming up through the polar plumes to account for all of the matter detected in space. If this conclusion is correct, the Sun is losing its mass at any given time through 10 or 20 channels, each of which has an X-ray bright point at its base. At a later time, different channels, with different X-ray bright points, are in operation. This conclusion agrees with the observations of the amount of matter flowing past the Earth, and with the number of X-ray bright points in coronal holes. The more X-ray bright points present in the coronal holes, the more matter flows past the Earth.

A rocket-borne instrument built at the Naval Research Laboratory has given us data even better than Skylab's. Although the rocket flights were much shorter than the flight of Sklylab — only a few minutes, rather than months — the instrument on board the rocket obtained solar spectra of extremely high resolution in ultraviolet wavelengths. These spectra suggest that highly localized events in the Sun's atmosphere release enough energy in a short time to drive a burst of mass away from the Sun. Once again, we are confronted with the possibility that the Sun may be losing mass in a more sporadic manner than we once believed.

Returning to the Skylab evidence, scientists note that since the temperatures are high in the X-ray bright points at the base of the plumes, an energetic process is at work. What else is known about the bright points besides the fact that they are hot? Astronomers who observe the Sun from Earth using special filters help search for magnetic fields on the Sun's surface. These astronomers have known for many years that a large number of small closed loops of magnetic fields are distributed over the entire surface of the Sun. When they compared their magnetic maps with the X-ray pictures, they found that all the X-ray bright points contained a closed loop of magnetic field. However, the opposite is not necessarily true. Many closed magnetic loops are not bright in X-rays. But the coincidence of bright points with closed loops makes us suspect that the energetic process driving the bright points has something to do with the field — perhaps something similar to a miniature flare. Whatever the energetic process, it sends gas upward at high speeds.



This sequence of X-ray light photographs taken about a day apart shows polar plumes on the surface of the Sun linked at the base to an X-ray bright point. Each day, new bright points appear and old ones disappear, but at least 10-20 exist at any given time. Photo courtesy Naval Research Laboratory.

At first glance, this contradicts the magnetic observations. After all, ground-based astronomers say that the magnetic fields are closed. If this is so, then the closed fields should trap gas, and prevent it from moving upwards. How can closed fields be reconciled with upward-shooting matter? The answer must be in the energetic process which must somehow change the field lines from closed to open. A magnetic reconnection process, important in flares, would do just that. It would release some energy in the form of heat, and raise the temperature in a small region in the immediate vicinity of the reconnection site enough to make it shine in X-rays.

The overall picture presented by the X-ray bright points indicates the presence of a twofold process. First, this process changes the field lines from closed to open, and allows mass loss; second, it helps drive the mass loss by forcing gas onto the opened field lines at high speed. Once the gas picks up enough speed, it escapes from the Sun. Even if an individual X-ray bright point is visible for only a few hours and then fades away, the gas it shot upward need not fall back into the Sun after a few hours. By that time, the gas is long gone. Though the X-ray bright points are transient features in the solar atmosphere, they cause the Sun to lose mass permanently. However, many other magnetic loops in the Sun's atmosphere are not associated with plumes of upward-moving matter. Only a small number of magnetic loops are unstable enough to throw off gas. For the most part, the magnetic field loops are long-lived and unrelated to mass loss.

Will these new ideas about the Sun help us understand the rapid mass loss of cool giant stars? The answer is still not clear. But in view of the fact that high pressure does not drive the rapid mass loss in these stars, it is tempting to call upon some kind of magnetic mechanism that efficiently ejects gas. Magnetic fields could certainly exist on the surfaces of cool giants for the same reason they appear on the surface of the Sun. In both cases, physical conditions beneath the surface are highly favorable for their creation.

For the sake of speculation, consider this: When a giant star crosses the boundary in the H-R diagram where coronae disappear and mass loss rates become rapid, perhaps something happens to the magnetic fields in the atmosphere to make all of the closed loops unstable. Two effects would then follow. First, there would be no long-lived closed loops in the stellar atmosphere to act as steady sources of coronal X-rays. The star would appear to have a coronal "hole" covering its entire surface. Second, every one of the magnetic loops that emerged from the stellar surface into the atmosphere would take part in the mass loss process. Rather than mass loss from only a dozen plumes or so (as in the Sun), mass would stream out from channels all over the surface of the star — wherever a magnetic loop popped up through the surface. Of course, other scenarios might also explain why mass loss suddenly becomes prominent and coronae disappear above this newly discovered boundary in the H-R diagram.

Stellar astrophysicists now confront a new challenge. The computer models that clarified the dot patterns found in the H-R diagrams of the 1950s did not factor in what happens in the coronae of stars. The new boundaries and patterns in the H-R diagram have been discovered so recently there has not been enough time to develop complete computer models to explain all the observations. As more attempts are made to derive suitable models, the next few years will be as exciting as the 1950s were for an earlier generation of astrophysicists.

From 1969 to 1972 Dermott Mullan was an astronomer at Armagh Observatory in Northern Ireland. He now researches the effects of magnetic fields in solar and stellar atmospheres for the Bartol Research Foundation.

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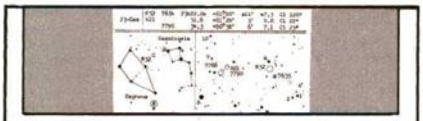

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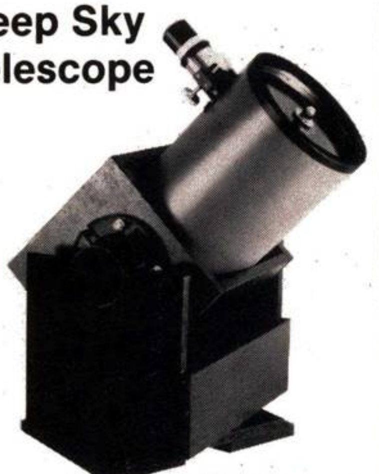

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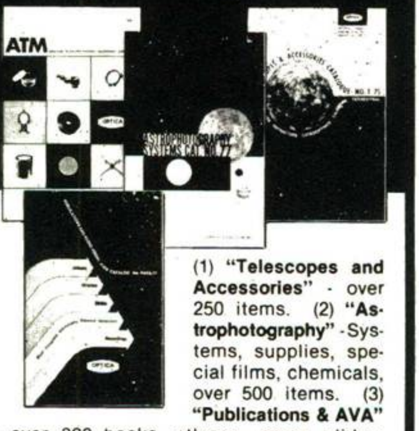

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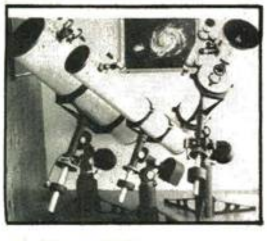

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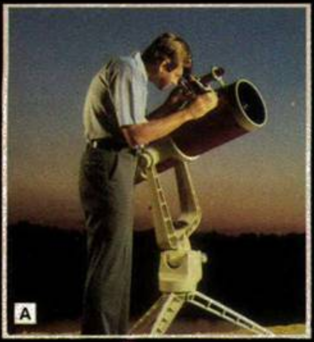

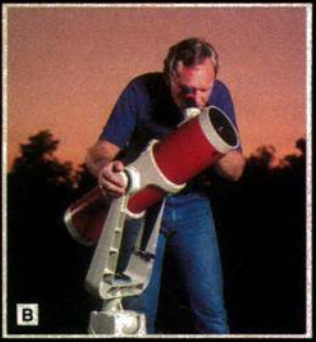

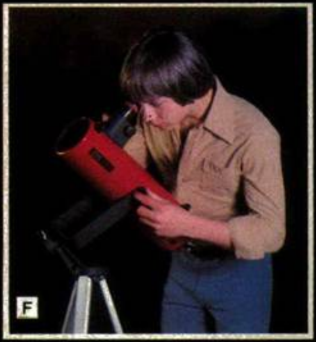

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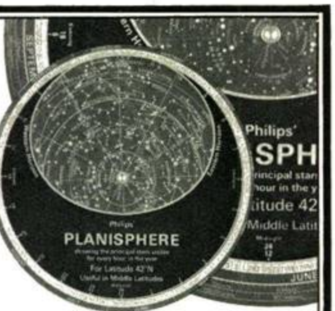

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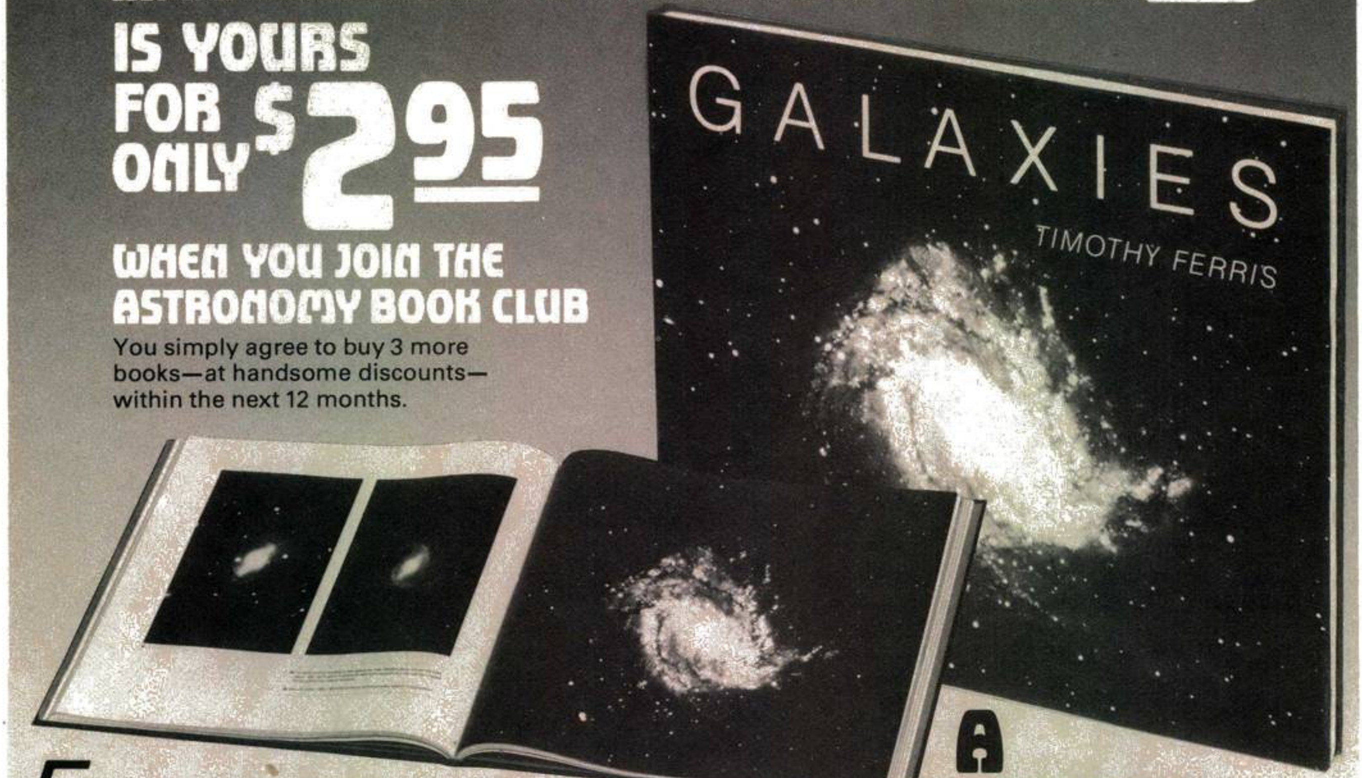

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the backyard astronomer

lepus

Mercury

This month, Mercury climbs to greatest eastern elongation on the 16th, pauses briefly, then sinks below the horizon again as it heads for inferior conjunction on the 31st. Your best chance to see it will be during the approach to elongation, because its climb will be more leisurely than its swift drop back to the horizon after elongation.

With Mercury's entire apparition compressed into about 25 days, you can note the changes in its phases almost on a day-to-day basis. When you first catch sight of it low in the southwest in early January, the planet will appear as a small, gibbous disk a little more than 5″ of arc in diameter. By greatest elongation, Mercury will appear half-lit, like a tiny First Quarter Moon, and it will have grown slightly to 7″ of arc. When it finally disappears from view, sometime around the 25th or 26th, Mercury's size will be up to nearly 9″ and the disk will be distinctly crescent-shaped.

Venus

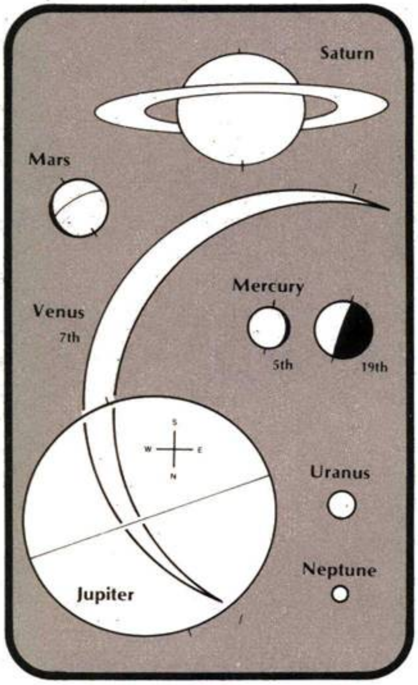
As Mercury is approaching greatest elongation, Venus will be descending toward inferior conjunction, which comes on January 20. On the evening of the 9th, bright Venus will pass about 5½° north of much dimmer Mercury. You'll get a better view with binoculars or your naked eye than with a telescope.

Venus is now so close to the horizon that if you wait until the sky is fully dark or almost so, you'll lose sight of it too early in the month. Instead, try observing it in twilight and see how far toward conjunction you can follow it. Your reward will be a sight of Venus' crescent becoming ever thinner and larger — up to more than a minute of arc across by the 15th.

The great globular cluster M-22 in Sagittarius spreads a third of a degree across in the sky and boasts a stellar population estimated at around 70,000. John Gleason, winner of January's "Best Astro-Photo" award, took this photo with a 1-hour exposure on ASA 400 film using a 14-inch Schmidt-Cassegrain at f/11.

Earth

At 11h UT on January 4th, Earth will be at perihelion, its closest approach to the Sun. Our planet will then be 0.9832947 AU or 147,098,919 kilometers from the Sun.



At present, the shape of the Earth's orbit is such that our planet receives maximum solar radiation at about the time of the northern hemisphere's winter solstice. This moderates what would otherwise be even larger seasonal changes in temperature on the land masses of the northern hemisphere.

By contrast, since its time of minimum solar radiation comes in winter and maximum in summer, you might expect the southern hemisphere to have drastic seasonal changes. It doesn't. The hemisphere's large expanses of ocean have great thermal inertia and heat up and cool off slowly. This prevents the seasonal temperature differences from becoming too extreme.

Mars

By midnight or 1 a.m. local time, Mars will have risen above the horizon murk in the east and will be seen easily as a reddish-orange "star" in the constellation Virgo. Moving steadily eastward parallel and a little north of the ecliptic, Mars will pass about 22′ of arc south of the double star Gamma (γ) Virginis on the 8th. This will be the first stage of a triple conjunction.

With a third of a degree separation between the star and planet, you'll need a low-power eyepiece — around 25x — to view the conjunction. When you center the two, look closely at the star. It is a fairly wide binary (just under 4″ of arc separation) with components of magnitudes 2.8 and 3.7.

On this date, Mars will be at magnitude +0.8 and will show a slightly gibbous disk 7.7″ of arc across. At present, Mars is nearing its summer solstice and the Earth is directly above the martian 22° north latitude.

Asteroids

1 Ceres (magnitude 8.3) is moving eastward from Virgo into Libra on a course that will take it close to the 2.6 magnitude star Beta (β) Librae early in February. Its positions:

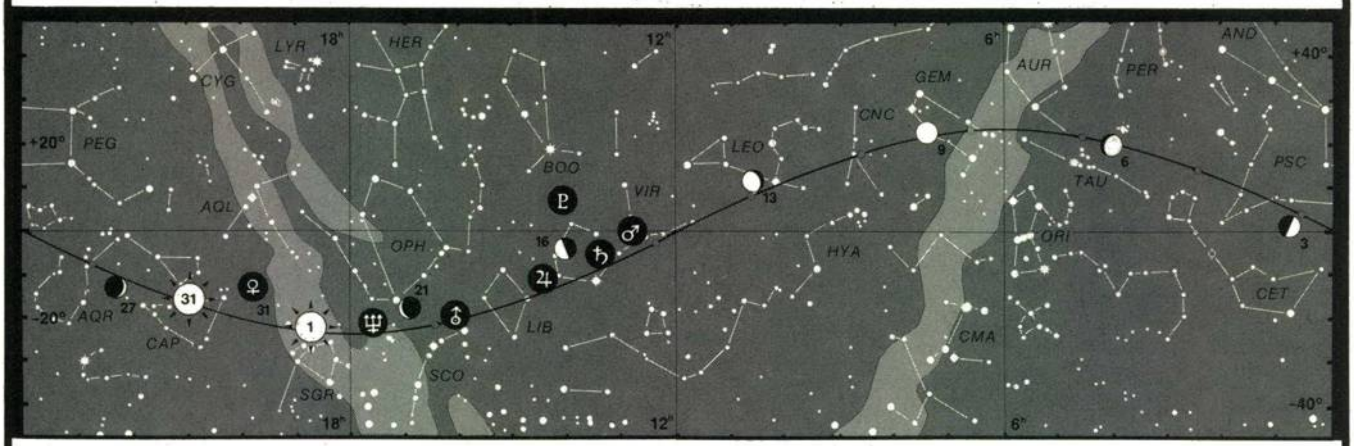
10th: 14h 47m 16s, -7° 17.9′
20th: 15h 00m 00s, -8° 05.3′

Ceres rises around 3:15 a.m. local time on the 15th.

2 Pallas (8.5) is moving northeastward between Mars and Jupiter in central Virgo. On the 13th, it will pass 1° 51′ to the south of the 4.4 magnitude star Theta (θ) Virginis. Its positions:

10th: 13h 02m 55s, 07° 30.4′
20th: 13h 13m 11s, -6° 20.6

planetary data january 1982


LYR
18h
HER
12h
6h
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AND
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CYG
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LEO
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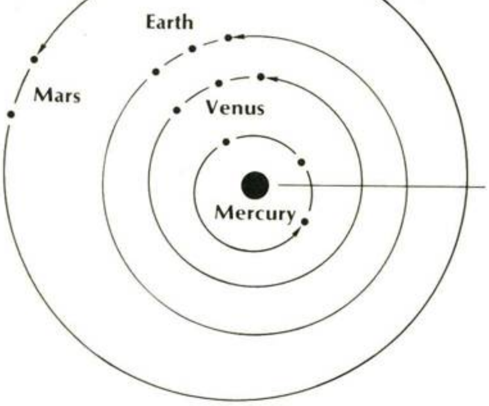
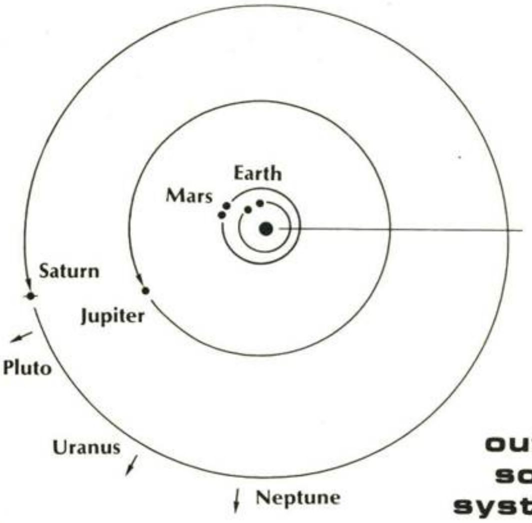
13
AQL
VIR
16
HYA
ORI
3
OPH
21
27
31
CET
-20°
AQR
31
1
CAP
LIB
CMA
SCO
SGR
18h
12h
6h
-40°

inner solar system


Earth
Mars
Venus
Mercury


Earth
Mars
Saturn
Jupiter
Pluto
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1982.1)	Dec
Sun		1	-26.8	32.6′	—	0.98	—	—	280°15.1′	18h 44.6m	-23°02.7′
		15	-26.8	32.6′	—	0.98	—	—	294°30.9′	19h 45.7m	-21°13.3′
		31	-26.8	32.5′	—	0.99	—	—	310°47.5′	20h 52.9m	-17°31.8′
Mercury	☿	1	-0.7	5.1″	93%	1.30	0.40	324°03.1′	292°05.4′	19h 38.8m	-23°40.9′
		15	-0.5	6.6″	63%	1.02	0.33	28°16.4′	312°37.2′	21h 03.6m	-17°35.6′
		31	+2.6	10.1″	1%	0.66	0.33	125°30.4′	312°55.2′	20h 59.4m	-13°35.8′
Venus	♀	10	-3.9	59.2″	5%	0.28	0.72	102°31.9′	306°31.2′	20h 34.2m	-14°49.9′
		31	-3.7	59.3″	4%	0.28	0.72	136°37.0′	295°19.6′	19h 45.3m	-13°38.3′
Mars	♂	15	+0.6	8.1″	91%	1.15	1.67	157°02.0′	191°46.5′	12h 49.2m	-2°30.6′
Jupiter	♃	15	-1.5	35.2″	99%	5.59	5.45	207°47.5′	217°26.2′	14h 23.8m	-12°59.8′
Saturn	♄	15	+0.9	17.5″	100%	9.55	9.64	196°09.9′	201°33.1′	13h 25.1m	-6°15.9′
Uranus	⛢	15	+6.0	3.5″	100%	19.46	18.86	241°02.9′	242°48.8′	16h 05.5m	-20°39.9′
Neptune	♆	15	+7.8	2.4″	100%	31.13	30.27	264°45.6′	265°10.0′	17h 41.2m	-22°06.8′
Pluto	♇	15	+14.0	—	100%	30.01	29.99	204°54.8′	206°18.9′	14h 04.2m	+5°35.1′

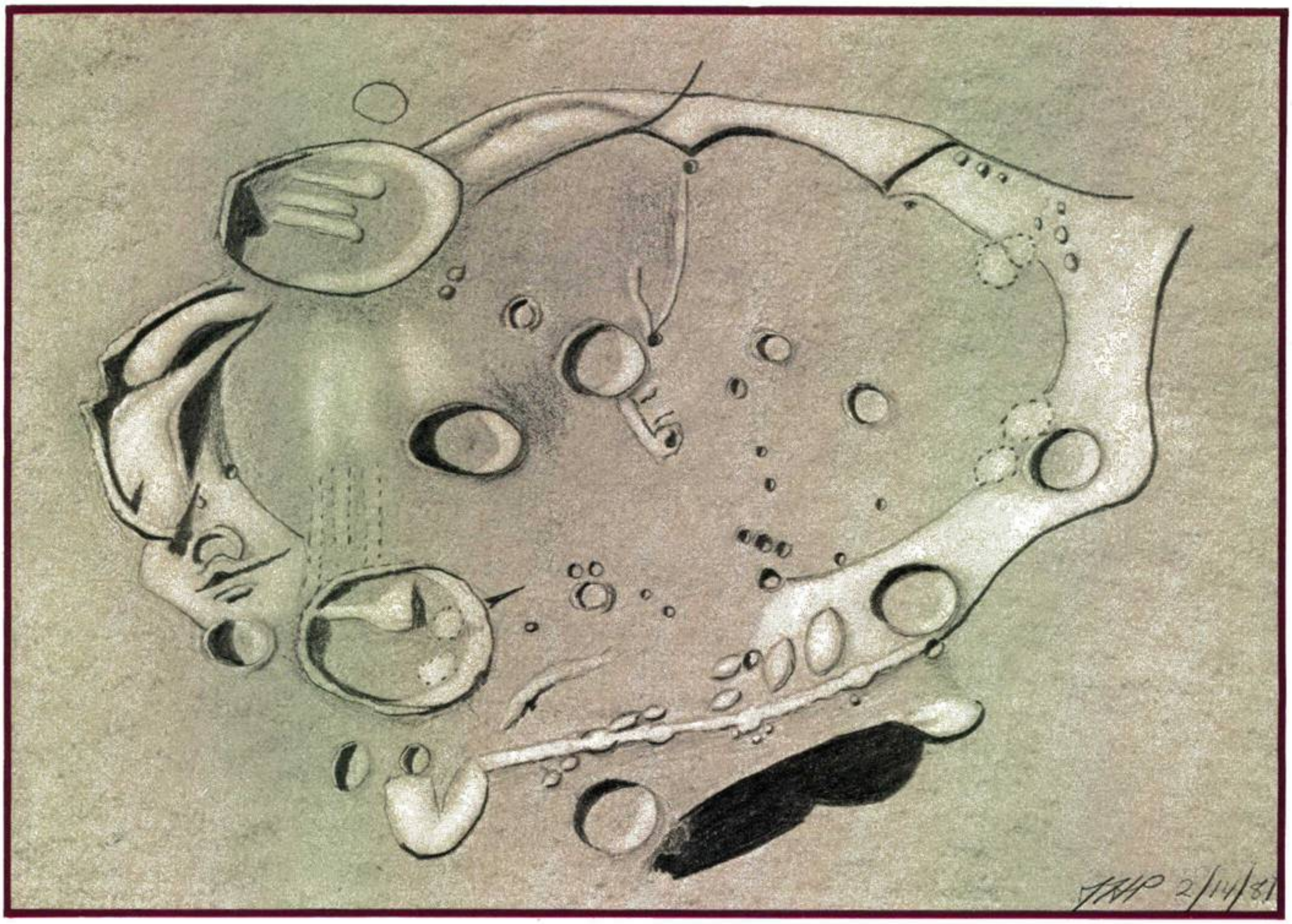
moon data

First Quarter	January	3 at	4:45
Full Moon	January	9 at	19:53
Last Quarter	January	16 at	23:58
New Moon	January	25 at	4:56
First Quarter	February	1 at	14:28
Full Moon	February	8 at	7:57

Perigee: January 8 at 12h 359,979km
Apogee: January 20 at 12h 405,375km

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on January 2, then EST for the event is 10 p.m., January 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m., March 4.



Though photography is quick and relatively easy, a careful drawing can bring out subtle detail observed during periods of steady seeing. Jim Phillips made this sketch of the large lunar crater Clavius. He used a 7-inch Maksutov with right-angle diagonal, 100x to 250x, and a pencil with soft, dark lead.

At mid-month, Pallas rises a little after midnight, local time.

3 Juno (11.5) lies in Ophiuchus in early January, but moves into Serpens (Cauda) by the end of the month. On the 19th it will pass about 17′ of arc north of the 4.3 magnitude star Nu (ν) Serpentis. Its positions:

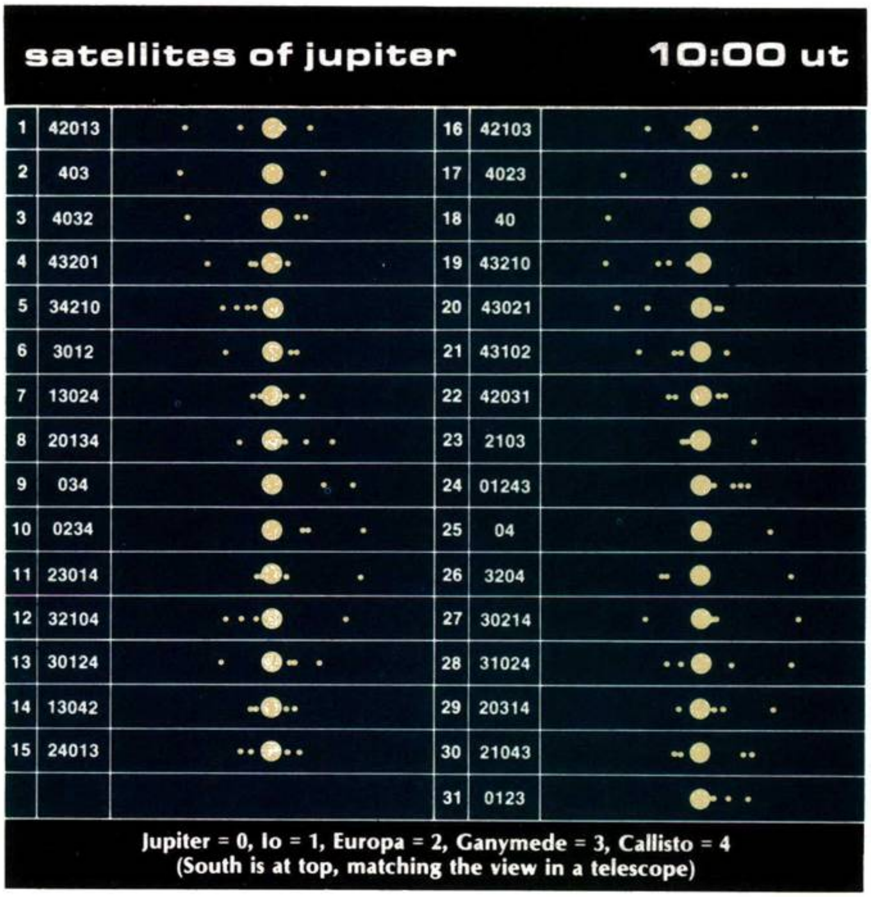
10th: 17h 05m 32s, -12° 31.6′
20th: 17h 18m 28s, -12° 31.1′

Juno rises about 5:30 a.m. local time on the 15th.

4 Vesta (7.8) is moving almost due eastward, about 7° south of Juno. It is heading toward NGC-6603, an open star cluster sometimes confused with M-24, a patch of Milky Way substantially larger. Vesta will pass about a degree and a half south of the cluster at the end of the month. Its positions:

10th: 17h 26m 41s, -20° 23.3′
20th: 17h 49m 08s, -20° 47.3′

Vesta rises about the same time as Juno: around 5:30 a.m. at mid-month.



satellites of jupiter **10:00 ut**

1	42013	16	42103
2	403	17	4023
3	4032	18	40
4	43201	19	43210
5	34210	20	43021
6	3012	21	43102
7	13024	22	42031
8	20134	23	2103
9	034	24	01243
10	0234	25	04
11	23014	26	3204
12	32104	27	30214
13	30124	28	31024
14	13042	29	20314
15	24013	30	21043
		31	0123

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

Above: On January 8, 1981, the Moon passed just south of Jupiter. Jean Dragesco, observing from Africa, photographed the conjunction. Right: The Moon and Mars were near Regulus in Leo when Bill Iburg photographed them during a bright aurora on October 22, 1982. The Big Dipper is at left.

(Asteroid positions are given in 1950 coordinates to facilitate plotting on star atlases.)

Jupiter

Jupiter rises around 3:30 a.m. local time on January 1. By the 31st it will appear around 1:30 a.m.

Early in the month, Jupiter will pass about three-quarters of a degree north of a 4th magnitude star, Lambda (λ) Virginis. Seeing both in the same telescopic field of view will call for a low-power eyepiece — 20x to 25x.

When you first start looking at Jupiter, the natural tendency is to use your highest power eyepiece. But all this will give you, most nights, is a large indistinct blob that you can't focus sharply. A high-power eyepiece magnifies not just the planet, but a lot of distortion in the Earth's atmosphere.

Use a power low enough to focus the image crisply and make it sit still. Before long, you'll discover that the amount of distortion varies from night to night. This is called "seeing" and it is the main limit to how much detail you can see on any given night. Don't blame the size of your telescope, or your eyepieces.

Saturn

Rising about an hour and a half before Jupiter and less than an hour after Mars, Saturn is conspicuous in the eastern sky around 1 a.m. Situated about 5° north of 1st magnitude Spica, the planet is only slightly brighter.

As the year opens, Saturn's ring system is tilted to our view by about 12.5°. This will slowly close up to about 9.6° in June and then open to 16.7° by year's end. The motion of the Earth around the Sun and the accompanying changes in perspective cause the see-saw effect.

Uranus

The keys to locating Uranus are the double stars Beta (β) and Omega (ω) Scorpii. At the beginning of the month, center the brighter component of Beta in your eyepiece, then shift your telescope about 2m of right ascension west and 46′ of arc south. By the end of the month, Uranus will lie about 3m of R.A. east of Beta and a little over a degree south of it.

From the 17th through the 19th, Uranus will be passing between the two stars that make up Omega. It will first pass 3.5′ of arc south of 4.0 magntiude Omega^1 and then 7′ of arc north of 4.3 magnitude Omega^2 two days later. Uranus will be a small disk 3.5″ of arc across at 6.0 magnitude.

Neptune

On the border between Ophiuchus and Scorpius at the edge of the Milky Way, Neptune still lies too close to the Sun to be seen except during twilight.

Meteors

The only strong meteor shower for January is the Quadrantid, which reaches peak activity at 19h UT on the 3rd. With most meteor showers, the name tells you where to look for the radiant. But in this case, the constellation that bestowed the name no longer exists. Formally titled Quadrans Muralis, after the mural quadrant — an early forerunner of the transit circle — the constellation was "created" by Joseph Lalande in 1795 out of stars in Hercules, Bootes, and Draco. Those constellations have since re-absorbed Quadrans.

The shower produces some 30 to 40 faint, fast, and bluish meteors per hour. To observe the Quads, you'll need a dark sky. This year, the Moon is at First Quarter and will be setting around midnight — so your chances are pretty good.

close-up on lepus

The dizzying rush of the holiday season has passed. Now that the guests are gone until next year and you've managed to recover from yet another

spate of New Year's resolutions, you can once again turn your thoughts to the unsurpassed beauty of the winter sky. It always seems there are more clear nights during the winter than in any other season. If tonight is one of them, don't tarry inside — this month's featured constellation is well-placed only in the early evening.

Low in the southwestern sky, at the feet of Orion, lies a small but interesting constellation that holds a respected place in both mythology and in the number of deep sky objects present within its boundary. Of course, we refer to **Lepus**, the hare. Close to the horizon and surrounded by a virtual jewel box of more famous constellations, Lepus is often passed over for richer star fields elsewhere. In any other season, observers would relish the vast number and variety of objects contained by this small, ancient constellation, but in the winter skies it is low on the observer's list.

Tonight start with Lepus — you won't be disappointed. In the words of T.W. Webb, this "little asterism, under the legs of Orion, is so near the horizon that it can only be seen well on the meridian, therefore, opportunities must not be thrown away." While Webb wrote these words years ago, the idea still comes across that a tardy observer will miss many fine sights.

Visually, Lepus is an easily recognizable parallelogram of second and third magnitude stars. **Alpha** (α), or **Arneb**, is a type F0 luminary that shines at magnitude 2.6. It is 900 light-years away, but 5,700 times brighter than the Sun. **Beta** (β), called **Nihal**, is a G5 star only 115 light-years distant, and is magnitude 2.8. Beta has an 11th magnitude companion that is difficult to resolve in all but the largest telescopes and is thought to be a type K dwarf.

Gamma (γ), a 3.6 magnitude F6 star, is a wide double with a very nice color contrast. Splitting it is easy in even the smallest scopes. The companion is nearly a naked-eye object — magnitude 6.1 — and its color differences have been argued for years. Smyth saw the pair as yellow and pale green; Webb thought they were pale yellow and garnet. E.J. Hartung described them as yellow and orange in his 1968 version of *Astronomical Objects for Southern Telescopes*, calling them a "brilliant wide pair — makes a beautiful low power object in a field sprinkled with stars." **Epsilon** (ϵ) completes the main figure and is type K5, 170 light-years distant at magnitude 3.2.

In London during the closing months of 1845, John Russell Hind discovered what is possibly the most striking stellar member of Lepus — **R Leporis**, the famous long-period

When Johannes Bayer cataloged the stars of Centaurus and included Omega among them, he perpetuated an ancient error. Known since 1677 to be a globular star cluster, Omega may contain over a million stars. David Healy used an 8-inch f/1.5 Schmidt camera, 100 ASA film, and a 2½ minute exposure.

pulsating red variable now known as **Hind's Crimson star**. At maximum, it has sometimes risen to near naked-eye level, but not in recent years. This star's color is remarkably distinct for an astronomical object — usually their hues are low threshold and more difficult to discern. Described by various observers, Hind's star has been called smoky red, a glowing coal, a ruby, or an illuminated drop of blood. Hind himself said it "was of the most intense crimson, resembling a blood-drop on the background of sky — no other star visible in these latitudes could compare with it." Hartung describes it as "a gleaming crimson jewel in a field well-sprinkled with stars." In 1905, Agnes Clerke decided that the hues of Betelgeuse and Antares were mere "pale shades" when compared to the wine-red color of R Leporis.

Since those days, R Leporis has been assigned to the spectral type N — classified with the other famous carbon stars. Its range of variability is from magnitude 5.9 to 11, and since 1970 its brightness has been increasing.

Lepus also harbors several galaxies that observers don't usually place at the top of their list. Although these systems are faint, they can be glimpsed in a 10-inch or larger scope.

NGC-1784 is a 12th magnitude galaxy described as almost circular in a 10-inch at low power, but with ill-defined edges and increasing brightness toward the center at high power. In a 16-inch, however, the shape becomes irregular and the center is extended. **NGC-1888** and **1889** are 14th magnitude galaxies, all but out of range for most backyard observers. In a 16-inch they are described as slightly extended with a well developed center that has a straight and sharply defined edge. NGC-1888 is almost stellar, and the area between it and 1889 is dark and sharp.

If these two extra-galactic systems defy your attempts at locating them, then simply swing your scope back around to Alpha Leporis. From Alpha draw an imaginary line to Beta and then extend it 4.4 degrees to the south. At the end of that line you'll find the only globular cluster visible in the winter sky — the forgotten **M-79**. It was discovered in October 1780 by Pierre Mechain and was again observed by Charles Messier in December of that year. It lies a mere 34 seconds of arc east-northeast from the double star **h3752**. It is an 8.4 magnitude object with a compact central mass measuring 2 seconds of arc in diameter. According to Sawyer's *Bibliography of Individual Globular Star Clusters*, M-79's full angular diameter is 7.8′. The cluster's integrated magnitude is 8.4 and its combined spectral type is F3. It appears to be about 50,000 light-years distant and its combined light from that distance indicates it might contain the equivalent of 90,000 suns.

Although it is not one of the brightest globulars, M-79 is stunning in any instrument. Mottling becomes noticeable with higher powers and with 8 to 10-inch instruments its outer edges begin to resolve into a "hazy sprinkling of 14th magnitude stars." Larger instruments reveal a "rich crowding of images toward the center." Sir William Herschel found it "beautiful and extremely rich" in his 20-foot telescope, while both Smyth and Webb described it as a round "nebula blazing toward the center." Before you pack up for the evening, what does it look like in your scope, on this night, in the year 1982 A.D.?

elongations of mercury & venus — 1982

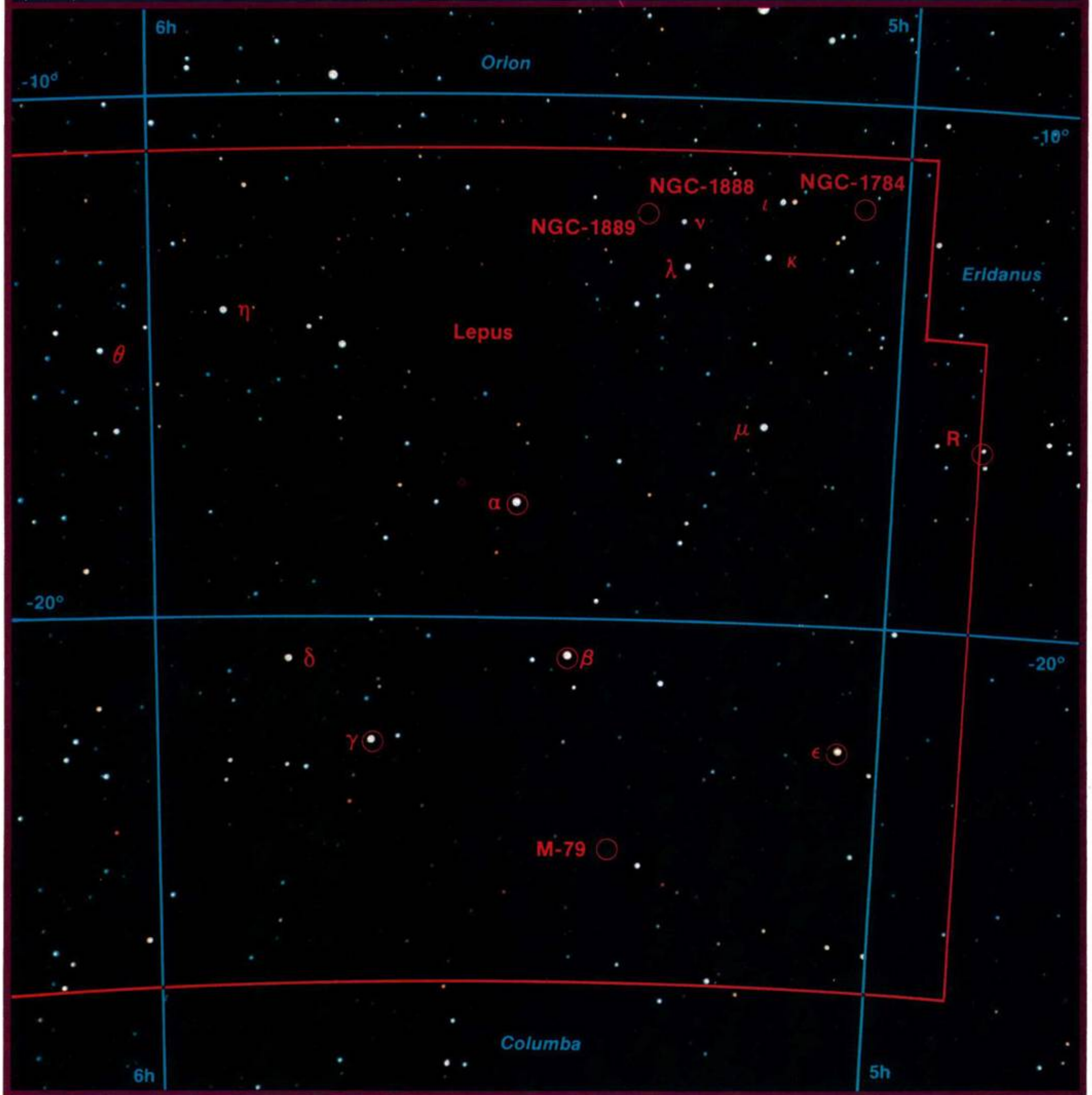
	Date	Altitude	Azimuth	Type & Extent of Elongation
Mercury	Jan. 16	8°	241°	East (evening sky), 19°
	Feb. 26	4°	117°	West (morning sky), 27°
	May 9	10°	293°	East (evening sky), 21°
	June 26	5°	69°	West (morning sky), 22°
	Sept. 6	1°	262°	East (evening sky), 27°
	Oct. 17	8°	98°	West (morning sky), 18°
	Dec. 30	7°	243°	East (evening sky), 20°
Venus	Apr. 1	13°	118°	West (morning sky), 46°

The planets' altitudes and azimuths are given for 45 minutes after sunset (east elongations) or 45 minutes before sunrise (west elongations) as seen by an observer at 40° north latitude. In other latitudes the figures will vary slightly. North = azimuth 0° or 360°, east = 90°, south = 180°, and west = 270°.

photo by John Sanford

lepus

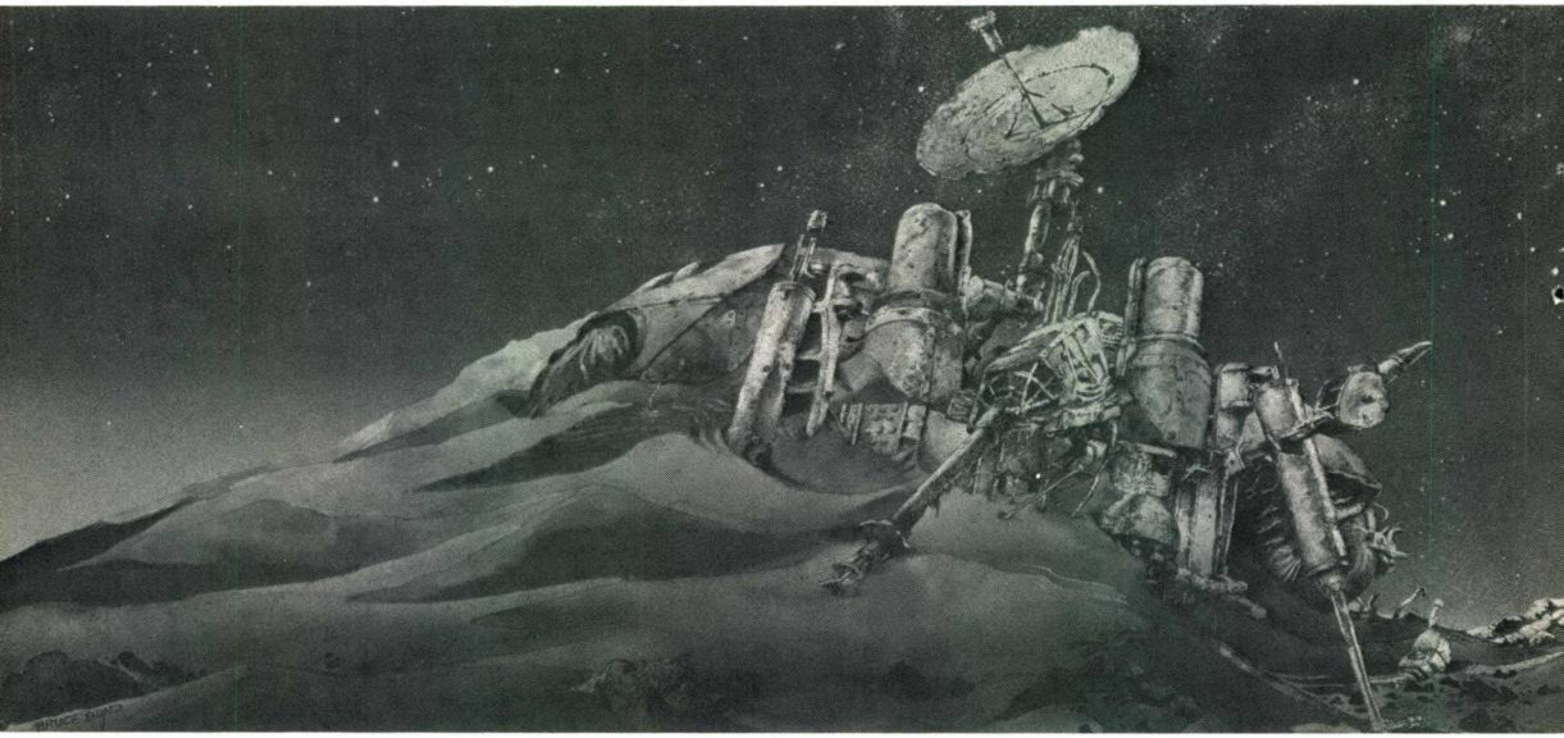
map by Robert Burnham


6h
5h
Orion
-10°
-10°
NGC-1888
NGC-1784
NGC-1889
ι
ν
λ
κ
Eridanus
η
θ
Lepus
μ
R
α
-20°
-20°
δ
β
γ
ε
M-79
Columba
6h
5h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1982)	Dec.
R	m★	5.9-11	432d	04h57m	-14°53′	04h59m	-14°50′
Epsilon (ε)	★	3.2	—	05h03m	-22°26′	05h05m	-22°24′
NGC-1784	§S	11.8	6′x4′	05h04m	-11°54′	05h06m	-11°51′
NGC-1888	§S	14.1	1′x1′	05h21m	-11°30′	05h23m	-11°28′
NGC-1889	§S	13.8	4′x1′	05h21m	-11°30′	05h23m	-11°28′
M-79	●	8.4	7.8′	05h22m	-24°34′	05h24m	-24°32′
Beta (β)	★²	2.8,11.0	2.5″	05h26m	-20°48′	05h27m	-20°46′
Alpha (α)	★	2.6	—	05h31m	-17°51′	05h32m	-17°50′
Gamma (γ)	★	3.6,6.1	95″	05h42m	-22°28′	05h44m	-22°27′

★	*Star*
★²	*Double Star*
★³	*Triple Star*
m★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

THE CHOICE IS YOURS!!!



VIKING – 500,000 A.D.

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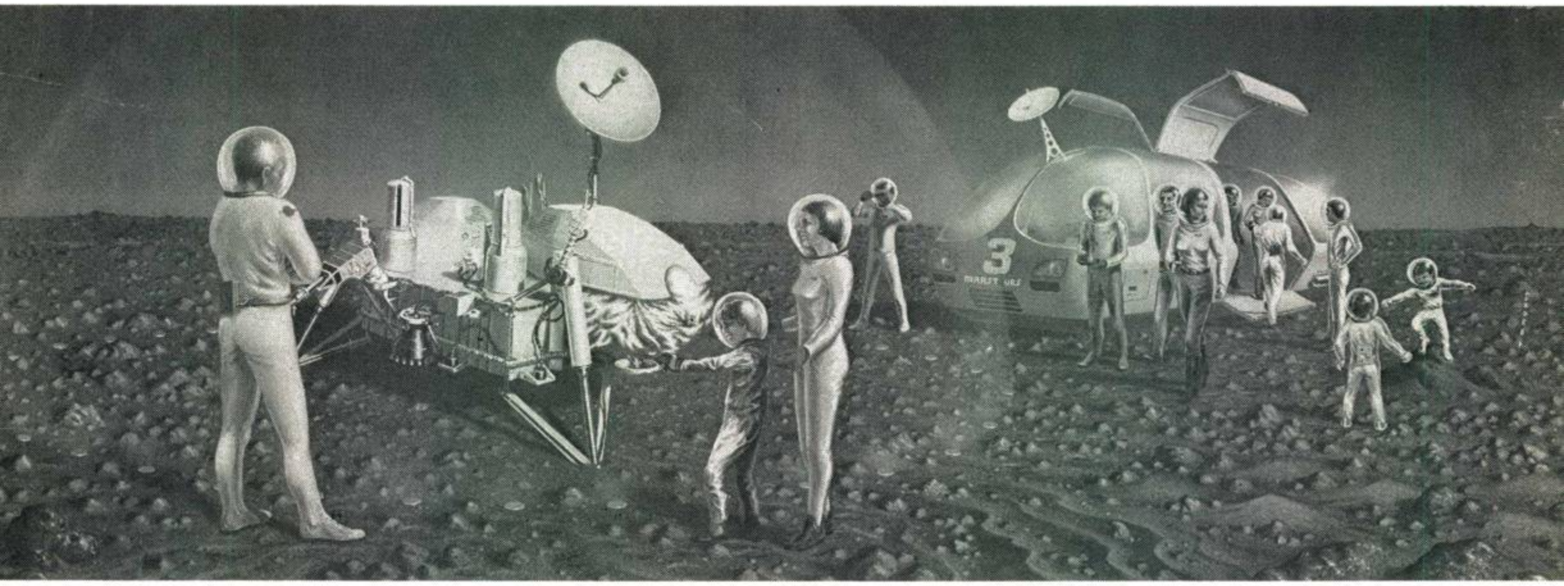

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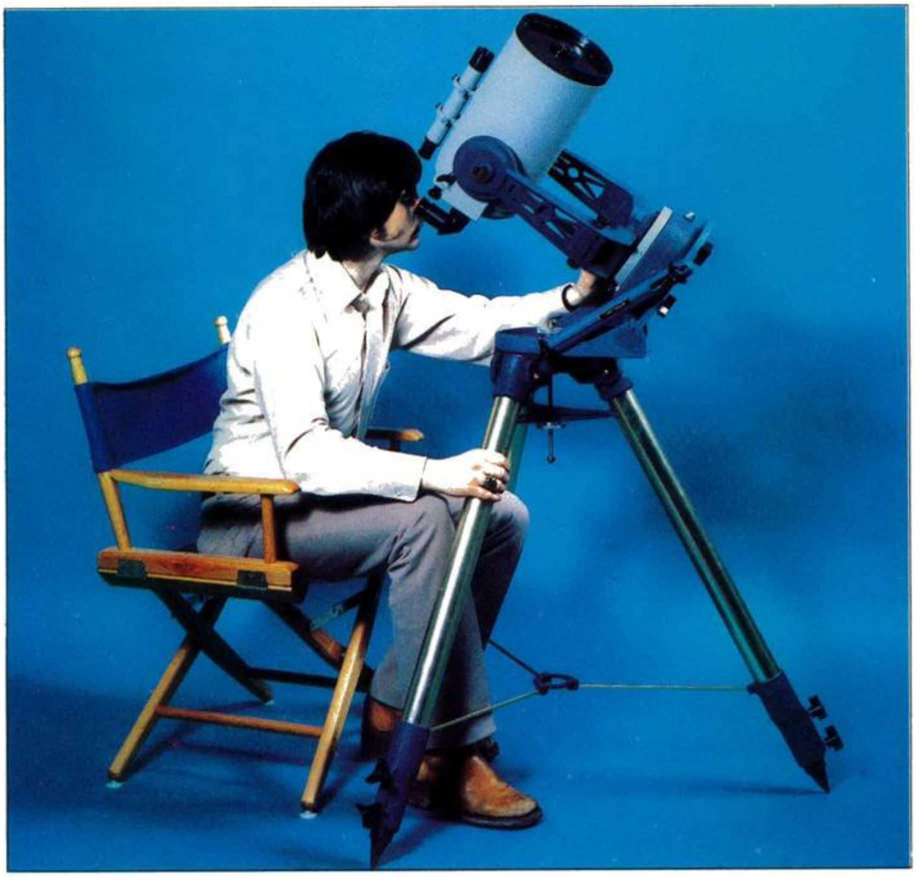

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